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Dredging Operations Technical Support Program

Risk of Pore Water Ammonia Toxicity in Dredged Material Bioassays

by Jerre G. Sims, David W. Moore

Prepared for Headquarters, U.S. Army Corps of Engineers

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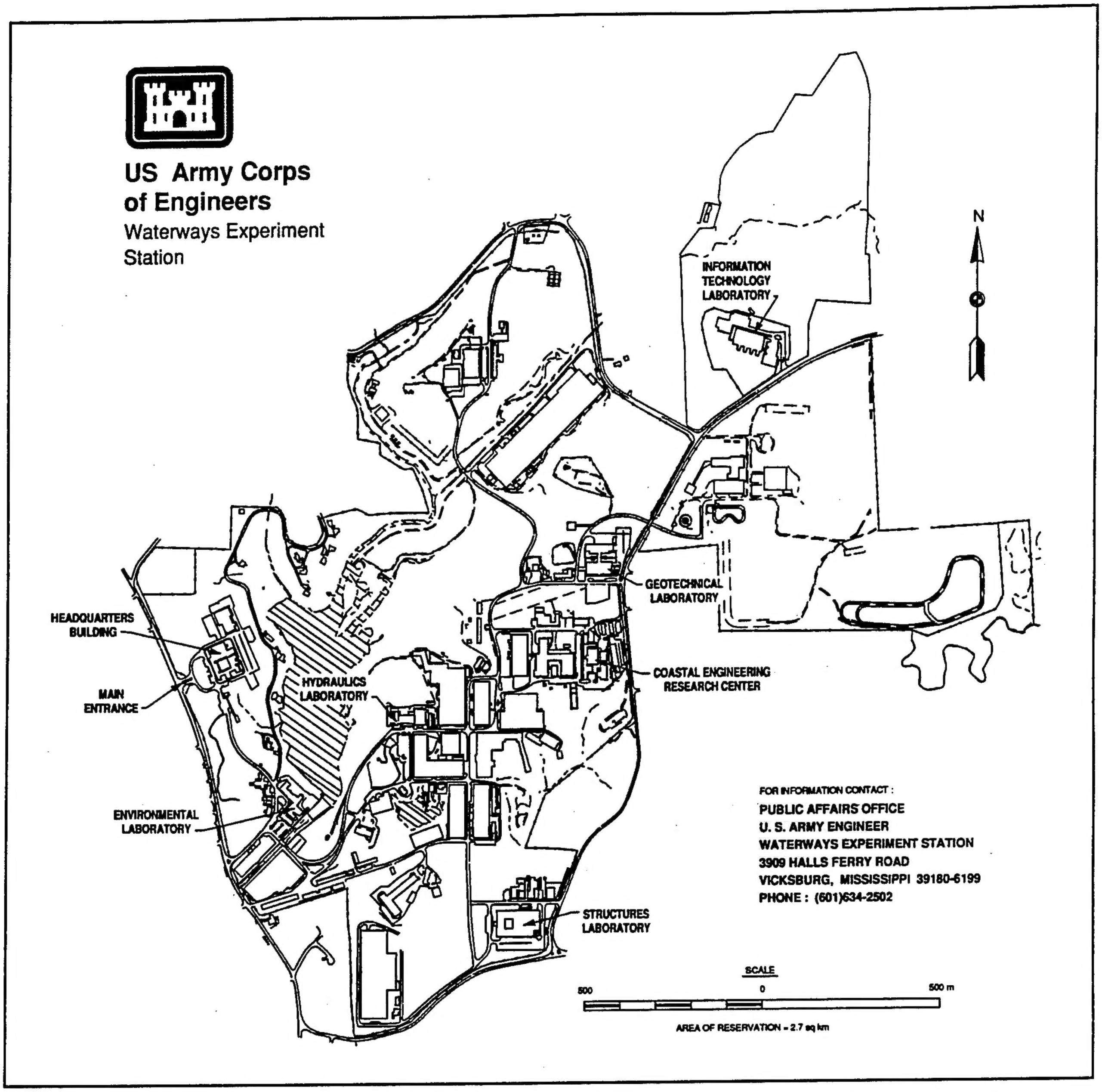

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Environmental Effects of Dredging Programs

Dredging Operations Technical Support

Report Summary

Risk of Pore Water Ammonia Toxicity in Dredged Material Bioassays (MP D-95-3)

ISSUE: In the past, ammonia has been treated as a contaminant of concern; but because it can exert toxicity effects, based upon whole sediment and elutriate toxicity tests, the potential of ammonia toxicity was evaluated.

RESEARCH: To evaluate the potential of hydrogen sulfide toxicity in dredged material bioassays, a literature review and survey were conducted. Data collected included pore water exposure concentrations and effects concentrations of laboratory studies.

SUMMARY: The comparison of reported exposure and effects concentrations suggests significant potential for ammonia toxicity in dredged material bioassays.

AVAILABILITY OF REPORT: The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, 3909 Halls Ferry Road, Vicksburg, MS39180-6199; telephone (601) 634-2355.

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About the Authors: Ms. Jerre Sims is a biologist in the WES Environmental Laboratory (EL), and Dr. David Moore is a research biologist, EL. For further information about the Dredging Operations Technical Support Program, contact Mr. Thomas R. Patin, Program Manager, at (601) 634-3444.

Contents

Preface

The work reported herein was conducted by the U.S. Army Engineer Waterways Experiment Station (WES) for Headquarters, U.S. Army Corps of Engineers (HQUSACE). Financial support was provided by the HQUSACE through the Dredging Operations Technical Support (DOTS) Program under the Work Unit "Influence of Non-contaminant Sediment Characteristics on Dredged Material Bioassays." The DOTS Program is managed by Mr. Tom Patin.

The report was prepared by Ms. Jerre G. Sims and Dr. David W. Moore, Environmental Processes and Effects Division (EPED), Environmental Laboratory (EL), WES.

Technical review was provided by Dr. Todd Bridges and Ms. Alfreda B. Gibson, EPED.

The work was performed under the general supervision of Dr. Bobby L. Folsom, Jr., Chief, Fate and Effects Branch, EPED. Chief of EPED was Mr. Donald L. Robey, and Director of EL was Dr. John W. Keeley.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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1 Purpose

Ammonia is a highly toxic, naturally occurring constituent of sediment pore water. It is not treated as a contaminant of concern for the regulatory evaluation of dredged material since it undergoes rapid oxidation and dilution during dredging and disposal. Because dredged material is evaluated using effects-based tests (i.e., whole sediment and elutriate toxicity tests), there is the potential for ammonia to exert toxicity and confound the regulatory decision-making process. This report evaluates the potential for ammonia toxicity in dredged material bioassays.

2 Approach

To characterize the potential for ammonia in dredged material bioassays, two types of information are required—exposure concentrations (i.e., concentrations of ammonia reported for sediment pore water) and effects concentrations (i.e., levels of ammonia shown to induce adverse effects in aquatic species). To collect exposure information, an extensive literature survey of published pore water concentrations of ammonia was conducted. In addition, information was requested on measured levels of ammonia associated with dredged material from every U.S. Army Corps of Engineers (USACE) Division and District. Information on exposure concentrations included reported concentration units, associated physical/chemical parameters (e.g., salinity, grain size, and total organic carbon), depth of sediment collection, and method of pore water collection and analysis. Literature was also reviewed for effects concentrations of ammonia shown to produce adverse effects in laboratory studies with aquatic species. Effects information included end points (e.g., lethality, growth, and reproduction), the concentration resulting in lethality or other effects in 50 percent of the test organisms (i.e., the LC_{50} or EC_{50}, respectively), the no observable effect concentration (NOEC), and the lowest observable effect concentration (LOEC) reported.

3 Background

Ammonia is a commonly occurring chemical that can exert toxicity at relatively low concentrations on fish and other aquatic organisms. Its presence in the environment may arise from sewage and industrial effluents, agricultural runoff, or as a naturally occurring metabolic by-product (Williams et al. 1986; Campbell 1973).

Ammonia is found in natural waters in both the un-ionized (NH_3) and the ionized (NH_4) form. Ammonia toxicity results primarily from the un-ionized fraction rather than the ionic component (Armstrong et al. 1978; U.S. Environmental Protection Agency (USEPA) 1984; Williams et al. 1986). The aqueous ammonia equilibrium is strongly dependent upon pH and temperature and to a lesser degree on ionic strength (Hampson 1977; Thurston, Russo, and Vinogradov 1981). Other factors that have been found to contribute to the toxicity of ammonia are low concentrations of dissolved oxygen, low levels of carbon dioxide (when pH levels are high), and salinities above and below blood isotonicity (European Inland Fisheries Advisory Commission (EIFAC) 1973). Concentrations of the un-ionized form increase with elevated temperature, pH values, and salinity (Bower and Bidwell 1978). Thurston, Russo, and Emerson (1979) found that 3 percent of total ammonia is in the un-ionized form in fresh water at a pH of 8.0 and temperature of 27 °C; in seawater at the same pH and temperature, 4 percent was in the un-ionized form. These parameters must be considered when identifying the form of ammonia that is responsible for toxicity. The USEPA (1989) has established chronic and acute water quality criteria for un-ionized ammonia in freshwater and marine systems. In freshwater systems, the un-ionized ammonia average chronic criterion is 0.02 mg/ℓ (1.2 µM/ℓ); for marine systems, the criterion is 0.04 mg/ℓ (2.3 µM/ℓ). Acute criterion values were reported as low as 0.08 mg/ℓ (4.7 µM/ℓ) for freshwater systems, while for marine systems, acute criterion was 0.5 mg/ℓ (29.4 µM/ℓ). The most sensitive organisms to ammonia are salmonids in freshwater systems and mysids, shrimp, and fish in marine systems.

Ammonia shows little tendency to sorb into sediments because of the high ionic concentration of salts present in marine pore water, the comparatively low concentration of ammonia, and the low sorption tendency of ammonia compared with the salts in pore water (Jones-Lee and Lee 1995). Under these

conditions, ammonia associated with sediment is usually dissolved in pore water.

There are a number of methods for the collection of pore water. Three of the most common methods are centrifugation, squeezing, and the use of in situ diffusion samplers. With the centrifugation method, aliquots of sediment are centrifuged, usually at low speed (e.g., 1,800 × g), for a set period of time (usually 15 to 30 min). Following centrifugation, pore water is decanted. Squeezer methods utilize a hydraulic or pneumatic collection device to squeeze an undisturbed sediment sample (core) under pressure, forcing pore water from the sediment through a filter membrane into a collection vessel. Diffusion samplers rely on simple diffusion of aqueous ammonia over time through a semipermeable membrane of a container placed directly in the sediment. Other collection methods include use of syringes, hand-suction pumps, and pipette samplers. These methods involve inserting the collection device into the sample and extracting pore water through a filter under vacuum.

The most commonly used methods for chemical analysis of ammonia in water include colorimetric techniques (e.g., nesslerization and phenate method) that rely on spectrophotometric analysis. Titration and use of ion selective electrodes are also common analytical techniques for ammonia analysis (American Public Health Association (APHA) 1985). Two major factors that influence the selection of methods are ammonia concentration and interferences (e.g., glycine, urea, glutamic acid, cyanates, acetamide, hydrazine, some amines, ketones, aldehydes, and alcohols). The Nessler method is sensitive down to 0.02 mg NH_3-N/ℓ (1.2 μM/ℓ) and, under optimal conditions (no interferences), up to 5 mg NH_3-N/ℓ (293.6 μM/ℓ). The manual phenate method has a range of 0.01 mg NH_3-N/ℓ (0.6 μM/ℓ) to 0.5 mg NH_3-N/ℓ (29.4 μM/ℓ). The phenate method can also be automated. Titration is useful for concentrations greater than 5 mg/ℓ NH_3-N (293.6 μM/ℓ). A potentiometric method using an ion-selective electrode is applicable to a range of 0.03 to 1,400 mg NH_3-N/ℓ (1.7-80,000 μM/ℓ).

4 Exposure Data

Pore water concentrations of ammonia were obtained from 39 publications covering 152 sites in freshwater, estuarine, and marine environments around the world. Sample locations are shown in Figure 1.

A summary of ammonia concentrations reported for sediment pore water is given in Table 1. Where concentrations were represented as total ammonia (i.e., ionized plus un-ionized) concentrations were converted to the un-ionized form based on reported pH, salinity, and temperature. When the necessary data (e.g., pH, temperature, and salinity) were not available, the following values were assumed: pH = 7.5, temperature = 20 °C, and salinity (0 for freshwater, 20 ppt for estuarine, and 30 ppt for marine systems). Conversions were made using the equation of Hampson (1977). The term "ammonia" is used throughout this paper to refer to the un-ionized form (NH_3). For comparative purposes, all reported ammonia concentrations were converted to micromoles per liter. Of the sites included in the literature review, 30 percent (47 of 152) were freshwater (i.e., salinity <1 ppt) with ammonia concentrations ranging from 0.12 to 25.7 µM/ℓ. Approximately 34 percent (51 of 152) of the sites were estuarine (i.e., salinity = 1 to 30 ppt) with reported ammonia concentrations ranging from 0.12 to 70.5 µM/ℓ. The remaining sites (35 percent or 54 of 152) were marine (i.e., salinity >30 ppt) with reported ammonia concentration ranging from 0.04 to 63.4 µM/ℓ.

When grain size was reported, generally only qualitative information was given (e.g., sand, silt, and clay). Based on this limited descriptive information, there did not appear to be a relationship between the sediment grain size and elevated levels of ammonia.

Sixty-seven percent (102 of 152 sites) of the studies reviewed reported total organic carbon (TOC). There does not appear to be a relationship between TOC and elevated ammonia concentrations (Table 1).

Many of the sites (85 percent or 129 of 152) reported pore water ammonia concentrations as a function of sediment depth. For data reported in this way, higher concentrations were associated with sediment deeper than 30 cm.

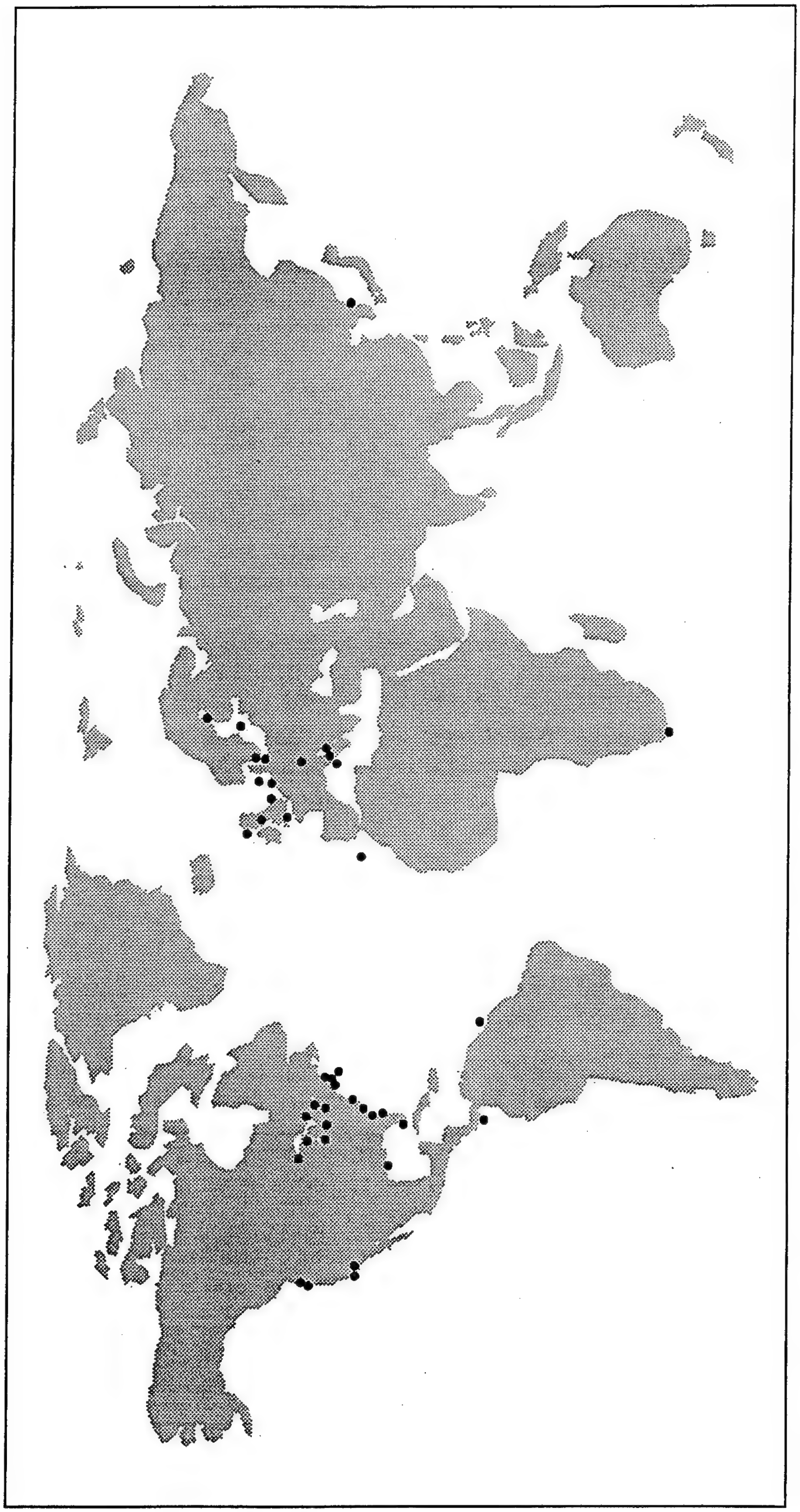

Figure 1. Location of sediment pore water samples reported in literature

The most commonly used method for pore water collection was by centrifugation (i.e., 39 percent or 59 of 152 sites for which a method was reported). Spectrophotometric procedures were the most frequently used methods of analysis (i.e., 74 percent or 113 of 152).

5 Dredged Material Data

Pore water concentrations of ammonia were obtained from seven U.S. Army Corps of Engineers Districts and Divisions and included 13 freshwater, 21 estuarine, and 5 marine sites. A summary of ammonia concentrations reported for sediment pore water in dredged material is given in Table 2.

In general, concentrations of pore water ammonia reported in the dredged material survey (median concentration = 13.9 µM/ℓ) were higher than values reported in the literature (median concentration = 1.3 µM/ℓ). Pore water ammonia concentrations for freshwater sites ranged from 1.06 to 662.4 µM/ℓ. Pore water ammonia concentration for estuarine sites ranged from 3.82 to 112 µM/ℓ. Reported pore water ammonia concentrations for marine dredged material sites ranged from 53.6 to 104.0 µM/ℓ.

Because of the lack of reported available data, no relationships could be established between sediment grain size, TOC, or depth of sediment collection with pore water ammonia concentration.

Similarly, very little information was provided regarding analysis. Of the methods reported, the most common methods of collection were centrifugation and squeezing; the only method of analysis given was the ion-selective electrode.

6 Effects Data

Effects concentrations of ammonia in aquatic organisms were obtained from 42 publications for 120 freshwater (i.e., 68 invertebrates and 82 fish) and 72 marine species (i.e., 49 invertebrates and 23 fish). Nearly all the studies reviewed (95 percent or 40 of 42) examined effects of ammonia using aqueous exposure (i.e., no sediments). Data are summarized in Table 3.

Freshwater invertebrates showed effects on survival at concentrations between 2.1 and 1,340 µM/ℓ. Reported effects on survival, growth, and/or other physiological responses for freshwater fish were found at concentrations between 1.2 and 423 µM/ℓ.

In this paper, median effect concentrations were similar for marine fish and marine invertebrates (48.5, 58.7 µM NH_3/ℓ, respectively). The median effects concentration for freshwater fish (44.9 µM NH_3/ℓ) was less than half of that for freshwater invertebrates (99.8 µM NH_3/ℓ). This suggests that freshwater invertebrates are much more tolerant of ammonia on the average than other species evaluated.

7 Discussion

A comparison of Tables 1, 2, and 3 indicates that effects concentrations are on average an order of magnitude higher than reported pore water ammonia concentrations. In an attempt to quantify these differences, exposure and effects data were plotted as cumulative probability curves (Figure 2). Effects data were plotted using either the LC50/EC50 information or, preferentially, the LOEC if available. This figure allows a direct comparison of exposure and effects data. The likelihood (i.e., probability) of occurrences for any particular

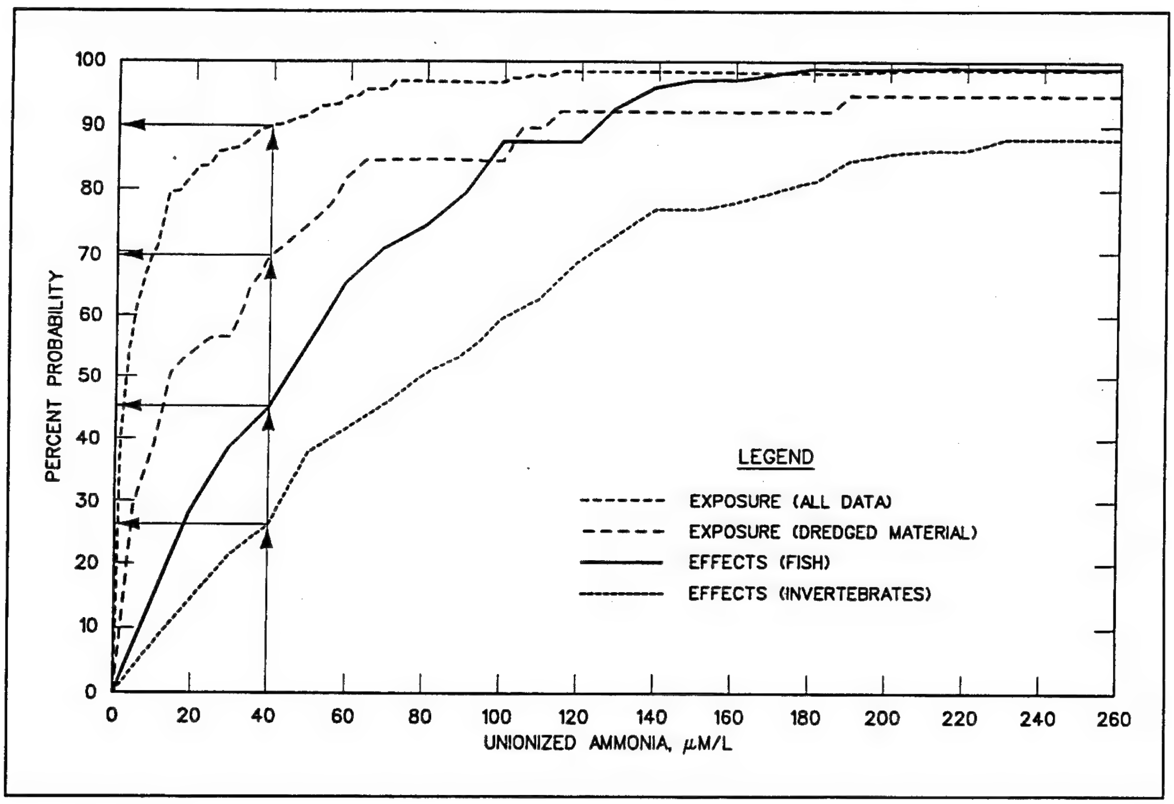

Figure 2. Probability distribution for biological effects concentrations ($\mu M\ NH_3/\ell$) and environmental sediments pore water exposure concentrations ($\mu M/\ell\ NH_3$) reported in literature

concentration along these curves can be determined by noting the corresponding "y" value for that concentration. For example, this figure indicates that 10 percent of all reported exposure concentrations (Tables 1 and 2) and nearly 30 percent of the reported dredged material exposure concentrations (Table 2 only) were >40 μM NH_3/ℓ (see arrows intersecting exposure curve, Figure 2). A similar evaluation of the effects distribution (Figure 2) shows a substantial number of reported effects concentrations (>45 percent for fish and >25 percent for invertebrates) were <40 μM NH_3/ℓ. This would suggest that the risk of pore water ammonia toxicity in dredged material bioassays may be significant.

Before any definite conclusions can be drawn regarding ammonia toxicity based upon exposure and effects concentrations, a number of potential biases must be considered.

Even if the data in Tables 1, 2, and 3 and Figure 2 are reflective of naturally occurring ammonia concentrations, organisms are not continuously exposed to these concentrations. A simplistic comparison of effects and pore water exposure concentrations may be misleading. For example, fish generally do not come into contact with undiluted pore water. The only time fish may come into contact with pore water ammonia in dredged material toxicity testing is during elutriate tests designed to evaluate the transient water column effects of dredged material disposal. During elutriate tests, whole sediment is slurried with dilution water in a 1:4 volume ratio (sediment:water), allowed to settle, and exposures are prepared from the resulting overlying water. In these tests, the risk of ammonia toxicity is probably small because of dilution and oxidation.

Secondly, whole sediment tests are usually conducted with benthic infaunal invertebrates. Many of these animals (e.g., polychaetes and amphipods) are tube builders that circulate oxygenated overlying water through burrows, substantially reducing or even eliminating exposure to pore water ammonia. The relative insensitivity of certain species (e.g., crayfish) to ammonia in aqueous exposures would suggest that physiological adaptations may also be possible (Table 3), though no data has been found in the literature to support such an assumption.

The sheer diversity of information and lack of comparability among data sets reviewed during this study (i.e., differences in collection, analysis, and reporting of data) make estimating the potential risk of pore water ammonia elevations in sediment toxicity problematic (only 2 of 43 studies reviewed reported exposing test organisms to sediments with adjusted pore water concentrations of ammonia). To provide a more certain estimate of the potential risk of pore water ammonia toxicity in dredged material bioassays, it would be necessary to begin collecting effects information in a way that reflects probable exposure (i.e., via sediment pore water). Dredged material data sets were not large enough to adequately characterize the distribution of ammonia exposure and effects concentrations. Until this information becomes available, the

assumption must be made on the basis of this review that sediment pore water ammonia represents potentially significant toxicant in dredged material bioassays.

References

Alabaster, J. S., Shurben, D. G., and Knowles, G. (1979). "The effect of dissolved oxygen and salinity on the toxicity of ammonia to smolts of salmon, *Salmo salar* L," *J. Fish Biol.* 15, 705-712.

Aller, R. C. (1980). "Diagenetic processes near the sediment-water interface of Long Island Sound. I. decomposition and nutrient element geochemistry," *Advances in Geophysics* 22, 237-350.

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. (1985). "Standard methods for the examination of water and wastewater," 16th ed., Washington, DC.

Ankley, G. T., Katko, A., and Arthur, J. W. (1990). "Identification of ammonia as important sediment-associate toxicant in the lower Fox River and Green Bay, Wisconsin," *Environ. Toxicol. and Chem.* 9, 313-322.

Armstrong, D. A., Chippendale, D., Knight, A. W., and Colt, J. E. (1978). "Interaction of ionized and un-ionized ammonia on short-term survival and growth of prawn larvae, *Macrobrachium rosenbergii*," *Biol. Bull.* 154, 15-31.

Arthur, J. W., West, C. W., Allen, K. N., and Hedyke, S. F. (1987). "Seasonal toxicity of ammonia to five fish and nine invertebrates species," *Bull. Environ. Contam. and Toxicol.* 124, 38, 324-331.

Bader, J. A., and Grizzle, J. M. (1992). "Effects of ammonia on growth and survival of recently hatched channel catfish," *Journal of Aquatic Animal Health* 4, 17-23.

Balzer, W. (1984). "Organic matter degradation and biogenic element cycling in a nearshore sediment (Kiel Bight)," *Limnol. Oceanogr.* 29(6), 1231-1246.

Boers, P., and de Bles, F. (1991). "Ion concentration in interstitial water as indicators for phosphorus release processes and reactions," *Water. Res.* 25(5), 591-598.

Bonanni, P., Caprioli, R., Ghiara, E., Mignuzzi, C., Orlandi, C., Paganin, G., and Monti, A. (1992). "Sediment and interstitial water chemistry of the Orgetello lagoon (Grosseto, Italy); nutrient diffusion across the water-sediment interface," *Hydrobiologia* 235/236, 553-568.

Bower, C., and Bidwell, J. P. (1978). "Ionization of ammonia in seawater: Effects of temperature, pH, and salinity," *J. Fish. Res. Board Can.* 35, 1012-1016.

Broderius, S., Drummond, R., Fiandt, J., and Russom, C. (1985). "Toxicity of ammonia to early life stages of the smallmouth bass at four pH values," *Environ. Toxicol. and Chem.* 4, 87-96.

Burton, D. T., and Fisher, D. J. (1990). "Acute toxicity of cadmium, copper, zinc, ammonia, 3,3'-Dichlorobenzidine, 2, 6-Dichloro-4-nitroaniline, methyl chloride, and 2,4,6-trichlorophenol to juvenile grass shrimp and killifish," *Bull. Environ. Contam. Toxicol.* 44, 776-783.

Campbell, J. W. (1973). "Nitrogen excretion," *Comparative animal physiology*. C. L. Prosser, ed., W. B. Saunders Company, Philadelphia, PA, 279-316.

Carr, R. S., Williams, J. W., and Fragata, C. T. B. (1989). "Development and evaluation of a novel marine sediment porewater toxicity test with the polychaete *Dinophilus gyrociliatus*," *Environ. Toxicol. and Chem.* 8, 533-543.

Chen, J. C., Ting, Y. Y., Lin, J. N., and Lin, M. N. (1990). "Lethal effects of ammonia and nitrate on *Penaeus chinensis* juveniles," *Mar. Biol.* 107, 427-431.

Colt, J., and Tchobanoglus, G. (1978). "Chronic exposure of channel catfish, *Ictalurus punctatus*, to ammonia: Effects on growth and survival," *Aquaculture* 15, 353-372.

de Beer, D., Sweerts, J-P. R. A., and van den Heuvel, J. C. (1991). "Microelectrode measurement of ammonium profiles in freshwater sediments," Federation of European Microbiological Societies, Microbiology Ecology, 8, 1-6.

DeGraeve, G. M., Overcast, R. L., and Bergman, H. L. (1980). "Toxicity of underground coal gasification condenser water and selected constituents to aquatic biota," *Arch. Environm. Contam. Toxicol.* 9, 543-555.

Dey, S., and Bhattacharya, S. (1989). "Ovarian damage to *channa punctatus* after chronic exposure to low concentrations of elsan, mercury, ammonia," *Ecotox. and Environ. Safety* 17, 247-257.

Diamond, J. M., Mackler, D. G., Rasnake, W. J., and Gruber, D. (1993). "Derivation of site-specific ammonia criteria for an effluent-dominated headwater stream," *Environ. Toxicol. and Chem.* 12, 649-658.

Emerson, S. (1976). "Early diagenesis in anaerobic lake sediments: Chemical equilibria in interstitial waters," *Geochemica et Cosmochimica Acta.* 40, 925-934.

Epifanio, C. E., and Srna, R. F. (1975). "Toxicity of ammonia, nitrite ion, nitrate ion, and orthophosphate to *Mercenaria mercenaria* and *Crassostrea virginica*," *Mar. Biol.* 33, 241-246.

European Inland Fisheries Advisory Commission (EIFAC). (1973). "Water quality criteria for European freshwater fish. Report on ammonia and island fisheries," *Water Res.* 7, 1011-1022.

Gersich, F. M., and Hopkins, D. L. (1986). "Site-specific acute and chronic toxicity of ammonia to *Daphnia magna* Straus," *Environ. Toxicol. and Chem.* 5, 443-447.

Hampson, B. L. (1977). "The analysis of ammonia in polluted sea water," *Water Res.* 11, 305-308.

Hickey, C. W., and Vickers, M. L. (1994). "Toxicity of ammonia to nine native New Zealand freshwater invertebrates species," *Arch. Environ. Contam. Toxicol.* 26, 292-298.

Ho, C. L., and Lane, J. (1973). "Interstitial water composition in Barataria Bay (Lousiana) sediment," *Estuar. Coast. Mar. Sci.* 1, 125-135.

Hopkinson, C. S., Jr. (1987). "Nutrient regeneration in shallow-water sediments of the estuarine plume region of the nearshore George Bight, USA," *Mar. Biol.* 94, 127-142.

Howes, B. L. (1985). "Effects of sampling technique on measurements of porewater constitutes in salt marsh sediments," *Limnol. Oceanogr.* 30(1), 221-227.

Jensen, M. H., Lomstein, E., and Sorensen, J. (1990). "Benthic NH_4 and NO_3-flux following sedimentation of a spring phytoplankton bloom in Aarhus Bight, Denmark," *Mar. Ecol. Pro. Ser.* 61, 87-96.

Johnson, C. G., and Crunkilton, R. L. (1994). "Effects of pH and hardness on chronic toxicity of ammonia to *Ceriodaphnia dubia*," *Society of Environmental Toxicity and Chemistry 15th annual meeting, 30 Oct-3 Nov., Denver, CO.*

Jones-Lee, A., and Lee, G. F. (1995). "Toxicity of ammonia in aquatic sediments and its implications for sediment quality evaluation and management," Draft. G. Fred Lee and Associates, El Macero, CA.

Kemp, W. M., Sampou, P., Caffrey, J., Mayer, M., Henriksen, K., and Boynton, W. R. (1990). "Ammonium recycling versus denitrification in Chesapeake Bay sediments," *Limnol. Oceanogr.* 35(7), 1545-1563.

Kristensen, E. (1993). "Seasonal variations in benthic community metabolism and nitrogen dynamics in a shallow, organic-poor Danish lagoon," *Estuarine, Coastal and Shelf Science* 36, 565-586.

Klump, J. V., and Martens, C. S. (1987). "Biogeochemical cycling in an organic-rich coastal marine basin. 5. Sedimentary nitrogen and phosphorus budgets based upon kinetic models, mass balances, and the stoichiometry of nutrient regeneration," *Geochimica et Cosmochimica Acta.* 51, 1161-1173.

Kohn, N. P., Word, J. Q., Niyogi, D. K., Ross, L. T., Dillon, T., and Moore, D. W. (1994). "Acute toxicity of ammonia to four species of marine amphipod," *Mar. Environ. Res.* 38, 1-15.

Krom, M. D., and van Rijn, J. (1989). "Water quality processes in fish culture system; processes, problems and possible solutions. *Aquaculture—A biotechnology in progress.* N. Depauw, E. Jaspers, H. Ackefors, and N. Wilkins, ed., European Aquaculture Society, Bredene, Belgium, 1091-1111.

Laima, M. J. C. (1992). "Extraction and seasonal variation of NH_4+ pools in different types of coastal marine sediments," *Mar. Ecol. Pro. Ser.* 82, 75-84.

Lerat, Y., Lasserre, P., and le Corre, P. (1990). "Seasonal changes in pore water concentrations of nutrients and their diffusive fluxes at the sediment-water interface," *J. Exp. Mar. Biol. Ecol.* 135, 135-160.

Lewis, W. J. (1988). "Uncertainty in pH and temperature correction for ammonia toxicity," *J. Water Pollut. Control Fed.* 60, 1922-29.

Lin, H., Thuet, P., Trilles, J., Mounet-Guillaume, R., and Charmantier, G. (1993). "Effects of ammonia on survival and osmoregulation of various development stages of the shrimp *Penaeus japonicus*," *Mar. Biol.* 117, 591-598.

Lohse, L., Malschaert, J. F. P., Slomp, C. P., Helder, W., and van Raaphorst, W. (1993). "Nitrogen cycling in North Sea sediments: Interaction of denitrification and nitrification in offshore and coastal areas," *Mar. Ecol. Prog. Ser.* 101, 283-296.

Mackin, J. E., and Aller, R. C. (1984). "Ammonium adsorption in marine sediments," *Limnol. Oceangr.* 29(2), 250-257.

Mackin, J. E., Aller, R. C., and Ullman, W. J. (1988). "The effects of iron reduction and nonsteady-steady diagenesis on iodine, ammonium, and boron distribution in sediments from Amazon continental shelf," *Continental Shelf Research* 8(4), 363-386.

Manissery, J. K., and Madhyastha, M. N. (1993). "Haematological and hispathological effect of ammonia at sublethal levels on fingerlings of common crap *Cyprinus carpio*," The Science of the Total Environment, Supplement 1993, Elsevier Science Publishers B.V. Amsterdam.

McLachlan, A. (1978). "A quantitative analysis of the meiofauna and the chemistry of the redox potential discontinuity zone in a sheltered sandy beach," *Estuarine and Coastal Marine Science* 7, 275-290.

Miller, D. C., Poucher, S., Cardin, J. A., and Hansen, D. (1990). "The acute toxicity of ammonia to marine fish and a mysid," *Arch. Environ. Contam. Toxicol.* 19, 40-48.

Moore, D. W., and Dillon, T. M. (1993). "Chronic sublethal effects of San Francisco Bay sediments on *Neris* (Neanthes) *arenaceodentata*: Full life-cycle exposure to bedded sediments," Long-Term Effects of Dredging Operations Program, Miscellaneous Paper D-93-2. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Murray, J. W., Grundmanis, V., and Smethie, W. M., Jr. (1978). "Interstitial water chemistry in the sediments of Saanich Inlet," *Geochimica et Cosmochimica Acta.* 42, 1011-1026.

Nedwell, D. B, Hall, S. E., Anderson, A., Hagstrom, A. F., and Lindstrom, E. B. (1984). "Seasonal changes in the distribution and exchange of inorganic nitrogen between sediment and water in the northern Baltic (Gulf of Bothnia)," *Estuar. Coast. Shelf Sci.* 17, 169-179.

Nimmo, D. W., Link, D., Parrish, L. P., and Davies, P. H. (1989). "Comparison of onsite and laboratory toxicity test: Derivation of site-specific criteria for un-ionized ammonia in a Colorado transitional stream," *Environ. Toxicol. and Chem.* 8, 1177-1189.

Ogle, R. S., and Hansen, S. R. (1994). "Ammonia and sediment toxicity," *Society of Environmental Toxicology and Chemistry 15th annual meeting 30 Oct-3 Nov 1994, Denver, CO.*

Oliff, W. D., Gardner, B. D., Turner, W. D., and Sharp, J. B. (1970). "The chemistry of the interstitial water as a measure of conditions in a sandy beach," *Water Res.* 4, 179-188.

Parkhurst, B. R., Bradshaw, A. S., Forte, J. L., and Wright, G. P. (1979). "An evaluation of the acute toxicity to aquatic biota of a coal conversion effluent and its major components," *Bull. Environm. Contam. Toxicol.* 23, 349-356.

Parkhurst, B. R., Meyer, J. S., DeGraeve, G. M., and Bergman, H. L. (1981). "A reevaluation of the toxicity of coal conversion process waters," *Bull. Environm. Contam. Toxicol.* 26, 9-15.

Pregnall, A. M., and Miller, S. L. (1988). "Flux of ammonium from surf-zone and nearshore sediments in Nahant Bay, Massachusetts, USA in relation to free-living *Pilayella littoralis*," *Mar. Ecol. Pro. Ser.* 50, 161-167.

Redner, B. D., and Stickney, R. P. (1979). "Acclimation to ammonia by *Tilipia aurea*," *Trans. American Fisheries Soc.* 108, 383-388.

Robinette, H. R. (1976). "Effect of selected sublethal levels of ammonia on the growth of a zirconium process effluent on juvenile salmonids," *Water Resour. Bull.* 11(5), 975-986.

Rosenfield, J. K. (1981). "Nitrogen diagenesis in Long Island Sound sediments," *American Journal of Science* 281, 436-462.

Science Applications International Corporation (SAIC). (1992). "Role of ammonia in toxicity tests used in evaluation of dredged material," EPA Contractor Report USAPA 27 Tarzwell Drive Narragansett, R.I., EPA Contract No. 68-C1-005, Work Assignment 13, Task 3 SAIC Project N. 2263, September 1992.

Schubauer-Berigan, M. K., and Ankley, G. T. (1991). "The contribution of ammonia, metals, and nonpolar organic compounds to the toxicity of sediment interstitial water from an Illinois River tributary," *Environ. Toxicol. and Chem.* 10, 925-939.

Servizi, J. A., and Gordon, R. W. (1990). "Acute lethal toxicity of ammonia and suspended sediment mixtures to Chinook Salmon (*Oncorhynchus tshawytscha*)," *Bull. Environ. Contam. Toxicol.* 44, 650-656.

Sholkovitz, E. (1973). "Interstitial water chemistry of the Santa Barbara Basin sediments," *Geochimica et Cosmochimica Acta.* 37, 2034-2073.

Sly, P. G. (1988). "Interstitial water quality of lake trout spawning habitat," *Journal of Great Lakes Research* 149(3), 301-315.

Solbé, J. F., De, L. G., and Shurben, D. G. (1989). "Toxicity of ammonia to early lifestages of rainbow trout (*Salmo gairdneri*)," *Water Res.* 23, 127-129.

Thurston, R. V., Chakoumakos, C., Russo, R. C. (1981b). "Effect of fluctuating exposures on the acute toxicity of ammonia to rainbow trout (*Salmo gairdneri*) and cutthroat trout (*S. clarki*)," *Water Res.* 15, 911-917.

Thurston, R. V., Phillips, G. R., Russo, R. C., and Hinkins, S. M. (1981a). "Increased toxicity of ammonia to rainbow trout (*Salmo gairdneri*) resulting from reduced concentrations of dissolved oxygen," *Can. J. Fish. Aquat. Sci.* 38, 983-988.

Thurston, R. V., Russo, R., and Emerson, K. (1979). "Aqueous ammonia equilibrium-tabulation of percent un-ionized ammonia," USEPA 600/3-79-091, Environmental Research Library, Duluth, MN.

Thurston, R. V., Russo, R. C., Luedtake, R. J., Smith C. E., Meyn, E. L., Chakoumakos, C., Wang, K. C., and Brown, C. J. D. (1984). "Chronic toxicity of ammonia to rainbow trout," *Trans. Am. Fish Soc.* 113, 56-73.

Thurston, R. V., Russo, R. C., Meyn, E. L., and Zajdel, R. K. (1986). "Chronic toxicity of ammonia to fathead minnows," *Trans. Am. Fish Soc.* 115, 196-207.

Thurston, R. V., Russo, R. C., and Phillips, G. R. (1983). "Acute toxicity of ammonia to fathead minnows," *Trans. Am. Fish Soc.* 112, 705-711.

Thurston, R. V., Russo, R. C., and Smith, C. E. (1978). "Acute toxicity of ammonia and nitrite to cutthroat trout fry," *Trans. Am. Fish Soc.* 107, 361-368.

Thurston, R. V., Russo, R. C., and Vinogradov, G. A. (1981). "Ammonia toxicity of fishes. Effects on pH on the toxicity of the un-ionized ammonia species," *Environ. Sci. Technol.* 15, 837-840.

Tisue, T., Edgington, D. N., and Seils, C. A. (1988). "Sulfate reduction in sediment interstitial fluids in Lakes Michigan and Erie," *Journal of Great Lakes Research* 14(1), 14-22.

Tomasso, J. R., Davis, K. B., and Simco, B. A. (1981). "Plasma corticosteroid dynamics in channel catfish (*Ictalurus punctatus*) exposed to ammonia and nitrite," *Can. J. Fish. Aquat. Sci.* 38, 1106-1112.

Tomasso, J. R., Goudie, C. A., Simco, B. A., and Davis, K. B. (1980). "Effects of environmental pH and calcium on ammonia toxicity in channel catfish," *Trans. Am. Fish. Soc.* 109, 229-234.

United States Army Corps of Engineers. (1994a). "Chemical analysis and toxicity evaluation of sediments at Toledo Harbor," U.S. Army Engineer District, Buffalo, Buffalo, NY.

United States Army Corps of Engineers. (1994b). "Chemical analysis and toxicity evaluation of sediments at Chicago Harbor," U.S. Army Engineer District, Chicago, Chicago, IL.

__________. (1994c). "Chemical analysis and toxicity evaluation of sediments at Oakland Harbor," U.S. Army Engineer District, San Francisco, San Francisco, CA.

__________. (1994d). "Chemical analysis and toxicity evaluation of sediments at Richmond Harbor," U.S. Army Engineer District, San Francisco, San Francisco, CA.

__________. (1994e). "Chemical analysis and toxicity evaluation of sediments at NY/NJ Federal Projects," U.S. Army Engineer District, New York.

United States Environmental Protection Agency. (1984). "Ambient water quality criteria for ammonia- 1984," Office of Water Regulations and Standards Division, Washington, DC, EPA 440/5-85-001.

__________. (1989). "Ambient water quality criteria for ammonia (saltwater)," Office of Water Regulations and Standards Criteria and Standards Division, Washington, DC, EPA 440/5-88-004.

van der Loeff, M. M. R. (1980). "Nutrients in the interstitial waters of the southern bight of the North Sea," *Netherlands Journal of Sea Research* 14(2), 144-171.

van Raaphorst, W., Kloosterhuis, H. T., Cramer, A., and Bakker, K. J. M. (1990). "Nutrient early diagenesis in the sandy sediments of the Dogger bank area, North Sea: Porewater results," *Netherlands Journal of Sea Research* 26(1), 25-52.

Viel, M., Barbanti, A., Langone, L., Buffoni, G., Paltrinieri, D., and Rosso, G., (1991). "Nutrient profiles in the pore water of a deltaic lagoon: Methodological considerations and evaluations of benthic flux," *Estuar. Coast. and Shelf Sci.* 33, 361-382.

Wajsbrot, N., Gasith, A., Krom, M. D., and Samocha, T. M. (1990). "Effects of dissolved oxygen and the molt stage on the acute toxicity of ammonia to juvenile green tiger prawn *Penaeus semisulcatus*," *Environ. Toxicol. and Chem.* 9, 497-504.

Watson, P. G., Frickers, P. E., and Goodchild, C. M. (1985). "Spatial and seasonal variations in the chemistry of sediment interstitial waters in the Tamar Estuary," *Estuar. Coast. and Shelf Sci.* 21, 105-119.

Watton, A. J., and Hawkes, H. A. (1984). "The acute toxicity of ammonia to copper to the gastropod *Potamopyrgus jenkinsi* (Smith)," *Env. Poll. (Ser.A)* 36, 17-29.

Weinrich, C. R., Tomasso, J. R., and Smith, T. I. J. (1993). "Toxicity of ammonia and nitrite to sunshine bass in selected environments," *J. Aquat. Animal Health* 5, 64-72.

Williams, K. A., Green, David, W. J., and Pasco, D. (1986). "Studies on the acute toxicity of pollutants to freshwater macroinvertebrates 3. Ammonia," *Arch. Hydrobiol.* 106(1), 61-70.

Winger, P. V., Lasier, P. J., and Geitner, H. (1993). "Toxicity of sediments and porewater from Brunswick Estuary, Georgia," *Arch. Environ. Contam. Toxicol.* 25, 371-376.

Young-Lai, W. W., Charmantier-Daures, M., and Charmantier, G. (1991). "Effect of ammonia on survival and osmoregulation in different lifestages of the lobster *Homarus americanus*," *Mar. Biol.* 110, 293-300.

Table 1
Sediment Pore Water Concentrations of Ammonia and Related Information (i.e., salinity, grain size, percent total organic carbon, depth of collection and methods of collection and analysis, and sample location) Reported in Literature

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
1.8 mg/ℓ	0.9	F.	N.R.[3]	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 12, East River, WI	Ankley, Kato, and Arthur 1990
6.3 mg/ℓ	3.0	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 11, Green Bay, WI	Ankley, Kato, and Arthur 1990
11.6 mg/ℓ	5.6	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 12, Green Bay, WI	Ankley, Kato, and Arthur 1990
20.3 mg/ℓ	9.9	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 1, Lower Fox River, WI	Ankley, Kato, and Arthur 1990
52.9 mg/ℓ	25.7	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 10, Lower Fox River, WI	Ankley, Kato, and Arthur 1990
40.9 mg/ℓ	19.8	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 2, Lower Fox River, WI	Ankley, Kato, and Arthur 1990
16.1 mg/ℓ	7.8	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 3, Lower Fox River, WI	Ankley, Kato, and Arthur 1990
21.8 mg/ℓ	10.4	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 4, Lower Fox River, WI	Ankley, Kato, and Arthur 1990
45.3 mg/ℓ	22.0	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 5, Lower Fox River, WI	Ankley, Kato, and Arthur 1990

(Sheet 1 of 15)

[1] Reported concentrations converted to un-ionized ammonia using reported pH and salinity and the equation of Hampson (1977). Values were converted from mg/ℓ to µM/ℓ using a conversion factor (58.71).
[2] F. = Freshwater (<1 ppt); E. = Estuarine (1 to 30 ppt); M. = Marine (30 to 35 ppt).
[3] N.R. = Not Reported.

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
52.6 mg/ℓ	25.5	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 6, Lower Fox River, WI	Ankley, Kato, and Arthur 1990
26.8 mg/ℓ	13.3	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 7, Lower Fox River, WI	Ankley, Kato, and Arthur 1990
18.8 mg/ℓ	9.1	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 8, Lower Fox River, WI	Ankley, Kato, and Arthur 1990
53.0 mg/ℓ	25.7	F.	N.R.	1.3-8.0	N.R.	Centrifuge	Ion Selective Electrode	Site 9, Lower Fox River, WI	Ankley, Kato, and Arthur 1990
1.1 mM/ℓ	12.6	F.	N.R.	N.R.	0-40	Squeezer	Ion Selective Electrode	Site LE38, Lake Erie	Tisue, Edgington, and Seils 1988
0.9 mM/ℓ	10.7	F.	N.R.	N.R.	0-40	Squeezer	Ion Selective Electrode	Site LE42, Lake Erie	Tisue, Edgington, and Seils 1988
0.1 mM/ℓ	0.9	F.	N.R.	N.R.	0-40	Squeezer	Ion Selective Electrode	Site LM18, Lake Michigan	Tisue, Edgington, and Seils 1988
0.2 mM/ℓ	2.4	F.	N.R.	N.R.	0-40	Squeezer	Ion Selective Electrode	Site LM5, Lake Michigan	Tisue, Edgington, and Seils 1988
0.01 mM/ℓ	0.1	F.	N.R.	N.R.	0-40	Squeezer	Ion Selective Electrode	Site LM6, Lake Michigan	Tisue, Edgington, and Seils 1988
0.3-0.6 mg/ℓ	0.03-0.11	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site L, Louisa, Algonquin State Park, Ontario,	Sly 1988
0.4-0.5 mg/ℓ	0.1-0.2	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site U, Louisa, Algonquin State Park, Ontario	Sly 1988

(Sheet 2 of 15)

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
0.4-0.7 mg/ℓ	0.1-0.2	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site (I), Louisa, Algonquin State Park, Ontario	Sly 1988
0.1-0.5 mg/ℓ	0.03-0.2	F.	Cobble/ gravel	1.88	4-8	In situ diffusion sampler	Spectro-photometric	Site L, Opeongo, Algonquin State Park, Ontario	Sly 1988
0.1-0.4 mg/ℓ	0.03-0.2	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site U, Opeongo, Algonquin State Park, Ontario	Sly 1988
0.1-0.5 mg/ℓ	0.03-0.2	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site (I), Oepongo, Algonquin State Park, Ontario	Sly 1988
0.2 mg/ℓ	0.1	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site (U), Oepongo, Algonquin State Park, Ontario	Sly 1988
0.4 mg/ℓ	0.1	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site U, Oepongo, Algonquin State Park, Ontario	Sly 1988
0.5-0.6 mg/ℓ	0.1-0.2	F.	Cobble/ gravel	3.9	4-8	In situ diffusion sampler	Spectro-photometric	Site C, Stony Island, E. Lake Ontario	Sly 1988
0.6-0.9 mg/ℓ	0.2-0.3	F.	Cobble/ gravel	3.9	4-8	In situ diffusion sampler	Spectro-photometric	Site E, Stony Island, E. Lake Ontario	Sly 1988
0.5 mg/ℓ	0.1	F.	Cobble/ gravel	3.0	4-8	In situ diffusion sampler	Spectro-photometric	Site W, Stony Island, E. Lake Ontario	Sly 1988

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
0.4-0.7 mg/ℓ	0.1-0.2	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site E, Yorkshire Island, E. Lake Ontario	Sly 1988
0.5 mg/ℓ	0.2	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site W, Yorkshire Island, E. Lake Ontario	Sly 1988
0.5-0.8 mg/ℓ	0.2-0.5	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site (E), Yorkshire Island, E. Lake Ontario	Sly 1988
0.5-1.7 mg/ℓ	0.2-0.5	F.	Cobble/ gravel	1.8	4-8	In situ diffusion sampler	Spectro-photometric	Site (W), Yorkshire Island, E. Lake Ontario	Sly 1988
0.5 mg/ℓ	0.1	F.	Cobble/ gravel	1.4	4-8	In situ diffusion sampler	Spectro-photometer	Keuka Lake, NY	Sly 1988
0.7 mg/ℓ	0.2	F.	Cobble/ gravel	1.4	4-8	In situ diffusion sampler	Spectro-photometric	Site L, Keuka Lake, NY	Sly 1988
0.3-0.6 mg/ℓ	0.01-0.02	F.	Cobble/ gravel	1.4	4-8	In situ diffusion sampler	Spectro-photometric	Site U, Keuka Lake, NY	Sly 1988
0.4 mg/ℓ	0.1	F.	Cobble/ gravel	1.4	4-8	In situ diffusion sampler	Spectro-photometric	Site (I), Keuka Lake, NY	Sly 1988
0.4-1.3 mg/ℓ	0.2-0.6	F.	Cobble/ gravel	0.2	4-8	In situ diffusion sampler	Spectro-photometric	Site N, Seneca Lake, NY	Sly 1988
0.5-1.0 mg/ℓ	0.2-0.3	F.	Cobble/ gravel	0.2	4-8	In situ diffusion sampler	Spectro-photometric	Site C, Seneca Lake, NY	Sly 1988
0.3-0.6 mg/ℓ	0.1-0.2	F.	Cobble/ gravel	0.2	4-8	In situ diffusion sampler	Spectro-photometric	Site S, Seneca Lake, NY	Sly 1988

(Sheet 4 of 15)

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
2.9 mg/ℓ	2.6	F.	N.R.	N.R.	0-14	In situ diffusion sampler	Spectro-photometric	Site 4, Lake Loosdrecht, The Netherlands	Boers and de Bles 1991
1.9 mg/ℓ	2.1	F.	N.R.	N.R.	0-14	In situ diffusion sampler	Spectro-photometric	Site 5, Lake Loosdrecht, The Netherlands	Boers and de Bles 1991
12.3 mg/ℓ	3.5	F.	N.R.	N.R.	0-14	In situ diffusion sampler	Spectro-photometric	Site 6, Lake Loosdrecht, The Netherlands	Boers and de Bles 1991
6.0 mg/ℓ	4.2	F.	N.R.	N.R.	0-14	In situ diffusion sampler	Spectro-photometric	Site 6A, Lake Loosdrecht, The Netherlands	Boers and de Bles 1991
1.3 mg/ℓ	1.1	F.	N.R.	N.R.	0-14	In situ diffusion sampler	Spectro-photometric	Site 9, Lake Loosdrecht, The Netherlands	Boers and de Bles 1991
0.3-0.4 mg/ℓ	0.08-0.1	F.	N.R.	N.R.	N.R.	Centrifuge	Ion Selective Electrode	Site C, Lake Vechten, The Netherlands	de Beer, Sweerts, and Van den Heuvel 1991
2.7 mg/ℓ	0.6	F.	N.R.	N.R.	0-52	Centrifuge	Spectro-photometric	Greifensee, N. Central Switzerland	Emerson 1976
0.4-0.6 mg/ℓ	0.2-0.3	E.	Sand/silt	1.0-2.0	0-2	Squeezer	N.R.	Site 1, San Francisco, San Pablo, CA	Carr, Williams, and Fragata 1989
0.8-1.0 mg/ℓ	0.2-0.4	E.	Sand/silt	1.0-2.0	0-2	Squeezer	N.R.	Site 3, San Francisco Bay, Vallejo, CA	Carr, Williams, and Fragata 1989

(Sheet 5 of 15)

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], μM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
0.3-0.5 mg/ℓ	0.7-0.9	E.	Sand/silt	1.0-2.0	0-2	Squeezer	N.R.	Site 1, San Francisco Bay, Yerba Buena, CA	Carr, Williams, and Fragata 1989
0.5 mg/ℓ	0.4	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Alcatraz Environs, San Francisco Bay, CA	U.S. Army Corps of Engineers 1994c
0.9-13.2 mg/ℓ	1.2-3.7	E.	N.R.	6.4	0-2.5	Vacuum sampler	Titration	Airplane Lake Barataria Bay, S. LA	Ho and Lane 1973
4.5-13.0 mg/ℓ	1.6-4.5	E.	N.R.	N.R.	0-2.5	Vacuum sampler	Titration	John the Fool Bayou, Barataria Bay, S. LA	Ho and Lane 1973
100.0-245.0 μM/ℓ	1.6-4.0	E.	Sand	1.0-1.8	0-35	Centrifuge	Spectro-photometric	Georgia Bight, Sapelo Island, GA	Hopkinson 1987
12.0 mg/ℓ	4.1	E.	N.R.	4.2-5.9	0-8	Centrifuge	N.R.	Site 1, Turtle River, Brunswick Estuary, GA	Winger, Lasier, and Geitner 1993
12.0 mg/ℓ	5.1	E.	N.R.	4.2-5.9	0-8	Centrifuge	N.R.	Site 2, Turtle River, Brunswick Estuary, GA	Winger, Lasier, and Geitner 1993
3.0 μM/ℓ	3.2	E.	N.R.	4.2-5.9	0-8	Centrifuge	N.R.	Site 3, Turtle Brunswick, Estuary, GA	Winger, Lasier, Geitner 1993
0.4-1.1 mM/ℓ	1.6-4.5	E.	N.R.	N.R.	0-12	Centrifuge	Spectro-photometric	Site 2, Chesapeake Bay	Kemp et al. 1990
0.6-1.3 mM/ℓ	10.7-23.1	E.	N.R.	N.R.	0-12	Centrifuge	Spectro-photometric	Site 1, Chesapeake Bay	Kemp et al. 1990

(Sheet 6 of 15)

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
0.4 mM/ℓ	7.1	E.	Silt/clay	0.6	1-5	Centrifuge	Spectro-photometric	Cooks Creek, SC	Mackin and Aller 1984
0.3 mM/ℓ	5.3	E.	Sand/silt/clay	N.R.	1-5	Centrifuge	Spectro-photometric	Mud Bay, SC	Mackin and Aller 1984
1.6-358.0 µM/ℓ	0.01-1.6	E.	Silt/clay	5.0-6.0	0-110	Squeezer	Spectro-photometric	Site DEEP, Long Island Sound	Aller 1980
156.0-1,400.0 µM/ℓ	0.2-2.1	E.	Silt/clay	2.0-5.0	0-140	Squeezer	Spectro-photometric	Site FOAM, Long Island Sound	Aller 1980; Rosenfield 1991
99.9-300.0 µM/ℓ	0.6-1.9	E.	Silt/clay	4.0-7.6	0-18	Squeezer	Spectro-photometric	Site NWC, Long Island Sound	Aller 1980; Rosenfield 1981
75.0 µM/ℓ	0.8	E.	N.R.	N.R.	0-20	In situ diffusion sampler	Spectro-photometric	Great Sipewissett S. Marsh, Cape Cod, MA	Howes 1985
0.6 mM/ℓ	9.9	E.	Silt/clay	0.6	0-30	Centrifuge	Spectro-photometric	Site 118, Amazon Shelf	Mackin, Aller, and Ullman 1988
1.0 mM/ℓ	16.0	E.	Silt/clay	0.6	0-30	Centrifuge	Spectro-photometric	Site 119, Amazon Shelf	Mackin, Aller, and Ullman 1988
0.1 mM/ℓ	1.6	E.	Silt/clay	0.6	0-30	Centrifuge	Spectro-photometric	Site 121, Amazon Shelf	Mackin, Aller, and Ullman 1988
1.0 mM/ℓ	16.5	E.	Silt/clay	0.6	0-30	Centrifuge	Spectro-photometric	Site 23, Amazon Shelf	Mackin, Aller, and Ullman 1988
0.8 mM/ℓ	12.4	E.	Silt/clay	0.6	0-30	Centrifuge	Spectro-photometric	Site 24, Amazon Shelf	Mackin, Aller, and Ullman 1988
0.4 mM/ℓ	6.6	E.	Silt/clay	0.6	0-30	Centrifuge	Spectro-photometric	Site 25, Amazon Shelf	Mackin, Aller, and Ullman 1988

(Sheet 7 of 15)

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
1.7 mM/ℓ	28.0	E.	Silt/clay	0.6	0-30	Centrifuge	Spectrophotometric	Site 41, Amazon Shelf	Mackin, Aller, and Ullman 1988
0.6 mM/ℓ	9.9	E.	Silt/clay	0.6	0-30	Centrifuge	Spectrophotometric	Site 42, Amazon Shelf	Mackin, Aller, and Ullman 1988
0.8 mM/ℓ	12.4	E.	Silt/clay	0.6	0-30	Centrifuge	Spectrophotometric	Site 47, Amazon Shelf	Mackin, Aller, and Ullman 1988
1.1 mM/ℓ	18.1	E.	Silt/clay	0.6	0-30	Centrifuge	Spectrophotometric	Site 52, Amazon Shelf	Mackin, Aller, and Ullman 1988
0-6.3 mM/ℓ	34.1	E.	Silt	3.2-4.0	0-140	In situ diffusion sampler	Spectrophotometric	Site 1, Saanich Inlet, British Columbia	Murray, Grundmanis, and Smethie 1978
0.01-5.7 mM/ℓ	0.2-128.5	E.	Silt	3.2-4.0	0-140	In situ diffusion sampler	Spectrophotometric	Site 2, Saanich Inlet, British Columbia	Murray, Grundmanis, and Smethie 1978
0.01-5.7 mM/ℓ	0.2-128.6	E.	Silt	3.2-4.0	0-140	In situ diffusion sampler	Spectrophotometric	Site 24, Sannich Inlet, British Columbia	Murray, Grundmanis, and Smethie 1978
0.01-2.1 mM/ℓ	0.2-47.3	E.	Silt	3.2-4.0	0-32	In situ diffusion sampler	Spectrophotometric	Site 25, Sannich Inlet, British Columbia	Murray, Grundmanis, and Smethie 1978
0.02-2.6 mM/ℓ	0.5-58.6	E.	Silt	3.2-4.0	0-28	In situ diffusion sampler	Spectrophotometric	Site 29, Sannich Inlet, British Columbia	Murray, Grundmanis, and Smethie 1978
300.0 µM/ℓ	6.0	E.	Silt/clay	2.3-5.7	0-10	Centrifuge	Spectrophotometric	Site C, Tamar Estuary, England	Watson, Frickers, and Goodchild 1985

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
250.0 µM/ℓ	3.6	E.	Silt/clay	2.3-5.7	0-10	Centrifuge	Spectro-photometric	Site H, Tamar Estuary, England	Watson, Frickers, and Goodchild 1985
250.0 µM/ℓ	3.0	E.	Silt/clay	2.3-5.7	0-10	Centrifuge	Spectro-photometric	Site I, Tamar Estuary, England	Watson, Frickers, and Goodchild 1985
500.0 µM/ℓ	3.0	E.	Silt/clay	2.3-5.7	0-10	Centrifuge	Spectro-photometric	Site S, Tamar Estuary, England	Watson, Frickers, and Goodchild 1985
214.0-223.3 µg/ℓ	0.2-0.5	E.	Silt	N.R.	1-20	Vacuum Sampler	Spectro-photometric	Site A, Port Erin Bay, S.W. Isle of Man, UK	McLachlan 1978
71.5-189.0 µg/ℓ	0.03-0.07	E.	Silt	N.R.	1-20	Vacuum Sampler	Spectro-photometric	Site B, Port Erin Bay, S.W. Isle of Man, UK	McLachlan 1978
3.8-97.0 µg/ℓ	0-0.002	E.	Silt	N.R.	1-20	Vacuum Sampler	Spectro-photometric	Site C, Port Erin Bay, S.W. Isle of Man, UK	McLachlan 1978
10.3-61.3 nM/ℓ	0-0.001	E.	N.R.	0.4-0.8	0-100	Centrifuge	Spectro-photometric	Faellesstrand Lagoon, N. Fin. Denmark	Kristensen 1993
20.0-135.0 nM/ℓ	0-0.001	E.	Silt	N.R.	0-9	Centrifuge	Spectro-photometric	Site D, Aarhys Bay, Jutland Denmark, E. Coast	Laima 1992
9.0-45.0 µM/ℓ	0.01-0.3	E.	Silt	N.R.	0-2	Centrifuge	Spectro-photometric	Aarhus Bight, Denmark, S.W. Kattegat	Jensen, Lomstein, and Sorensen 1990

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
100.0-400.0 nM/ℓ	0-0.001	E.	Silt	N.R.	0-9	Centrifuge	Spectro-photometric	Site F, Norsmide Fjord, Jutland Denmark, E. Coast	Laima 1992
10.0-150.0 nM/ℓ	0-0.003	E.	Silt	N.R.	0-9	Centrifuge	Spectro-photometric	Site E, Randers Fjord, Jutland Denmark, E. Coast	Laima 1992
5.8-215.0 µM/ℓ	0.02-0.6	E.	Silt	N.R.	0-15	Centrifuge	Spectro-photometric	Gulf of Bothnia, Norrbyn, N. Baltic, E. Sweden	Nedwell et al. 1984
0.4-12.4 µM/ℓ	0-0.13	E.	Sand/silt	1.0-2.3	0-20	Squeezer	Ion Selective Electrode	Kiel Bight, Western Baltic Sea	Balzer 1984
848.0-1,116.0 µM/ℓ	9.5-12.4	E.	Silt/clay	1.0-3.6	0-30	Centrifuge	Spectro-photometric	Site A, N.W. Italy, Adriatic Sea	Viel et al. 1991
803.0-1,185.0 µM/ℓ	5.7-8.4	E.	Silt/clay	1.0-3.6	0-30	Centrifuge	Spectro-photometric	Site B, N.W. Italy, Adriatic Sea	Viel et al. 1991
56.0 µg/ℓ	0.04	E.	Silt	N.R.	N.R.	In situ diffusion sampler	Spectro-photometric	Umgeni River mouth, S. Africa	Oliff et al. 1970
233.0 µM/ℓ	0.1	E.	Silt	N.R.	N.R.	In situ diffusion sampler	Spectro-photometric	Umlaas Canal, S. Africa	Oliff et al. 1970
10.9 mg/ℓ	6.9	M.	N.R.	N.R.	N.R.	N.R.	N.R.	West Beach, WA	U.S. Army Corps of Engineers 1994e
10.1-16.0 mg/ℓ	3.9-37.4	M.	Sand/silt/clay	0.03-0.84	0-2.5	Centrifuge	Ion Selective Electrode	Sequim Bay, WA	Moore and Dillon 1993; U.S. Army Corps of Engineers 1994e

(Sheet 10 of 15)

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
0.6-0.9 mg/ℓ	0.3-0.4	M.	N.R.	1.5-9.3	0-48	Squeezer	N.R.	Site 1, Tomales Bay, CA	Carr, Williams, and Fragata 1989
736.0 µM/ℓ	10.8	M.	Clay	1.9-2.6	0-30	Centrifuge	Spectro-photometric	Site B, Santa Barbara Basin, CA	Sholkovitz 1973
657.0 µM/ℓ	9.6	M.	Clay	1.0-3.0	0-30	Centrifuge	Spectro-photometric	Site G1, Santa Barbara Basin, CA	Sholkovitz 1973
118.5 µM/ℓ	1.8	M.	Clay	1.0-3.0	0-30	Centrifuge	Spectro-photometric	Site G2, Santa Barbara Basin, CA	Sholkovitz 1973
4.6-4.8 mg/ℓ	10.7-11.1	M.	Sand/silt/clay	0.03-0.84	0-2.5	Centrifuge	Ion Selective Electrode	San Francisco Bay, Alcatraz Env.	Moore and Dillon 1993
5.4-5.6 mg/ℓ	10.0-10.3	M.	Sand/silt/clay	0.03-0.84	0-2.5	Centrifuge	Ion Selective Electrode	San Francisco Bay, Alcatraz Mound	Moore and Dillon 1993
17.0-17.5 mg/ℓ	49.1-50.6	M.	Sand/silt/clay	0.03-0.84	0-2.5	Centrifuge	Ion Selective Electrode	San Francisco Bay, Bay Farm	Moore and Dillon 1993
21.5-22.0 mg/ℓ	49.8-51.0	M.	Sand/silt/clay	0.03-0.84	0-2.5	Centrifuge	Ion Selective Electrode	San Francisco Bay, Pt. Reyes	Moore and Dillon 1993
0.3 mM/ℓ	2.5	M.	Sand/silt/clay	0.3-4.0	1-5	Centrifuge	Spectro-photometric	Trout Cove, FL	Mackin and Aller 1984
1.0-3.0 mM/ℓ	10.0-30.6	M.	Silt	3.0-5.0	0-20	Centrifuge	Spectro-photometric	Cape Lookout, NC	Klump and Martens 1987
9.8 mg/ℓ	4.0	M.	N.R.	N.R.	N.R.	N.R.	N.R.	Amplesca Native Control	U.S. Army Corps of Engineers 1994e
5.8-5.9 mM/ℓ	44.5-45.1	M.	N.R.	1.0-3.0	0-150	Squeezer	Titration	Long Island Sound, Sachem	Rosenfield 1988

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
0.01-0.1 µM/ℓ	0-0.001	M.	Sand	N.R.	0-10	Vacuum sampler	Spectro-photometric	Site CGB, Nahant Bay, MA	Pregnall and Miller 1988
1.5-3.0 µM/ℓ	0.01-0.02	M.	Sand	N.R.	N.R.	Vacuum sampler	Spectro-photometric	Site LNN, Nahant Bay, MA	Pregnall and Miller 1988
0.01-1.5 µM/ℓ	0-0.01	M.	Sand	N.R.	N.R.	Vacuum sampler	Spectro-photometric	Site LSD, Nahant Bay, MA	Pregnall and Miller 1988
0.01-0.1 µM/ℓ	0-0.001	M.	Sand	N.R.	0-10	Vacuum sampler	Spectro-photometric	Site TIDES, Nahant Bay, MA	Pregnall and Miller 1988
0.1-0.2 mg/ℓ	0.1-0.2	M.	Sand/silt	N.R.	0-20	Squeezer	N.R.	Duxbury Bay, MA	Carr, Williams, and Fragata 1989
0.02 mM/ℓ	0.1	M.	Sand/silt/clay	0.3-4.0	1-5	Centrifuge	Spectro-photometric	Western Atlantic	Mackin and Aller 1984
0.02 mM/ℓ	2.5	M.	Sand/silt/clay	0.3-4.0	1-5	Centrifuge	Spectro-photometric	Panama Basin	Mackin and Aller 1984
6,200.0 µM/ℓ	63.4	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site C, Southern Bight of North Sea	van der Loeff 1980
105.0 µM/ℓ	1.1	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Southern Bight of North Sea, Coastal Survey	van der Loeff 1980
1,200.0 µM/ℓ	12.2	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site D, Southern Bight of North Sea	van der Loeff 1980
1,000.0 µM/ℓ	10.2	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site E, Southern Bight of North Sea	van der Loeff 1980
27.5 µM/ℓ	0.3	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site G1, Southern Bight of North Sea	van der Loeff 1980

(Sheet 12 of 15)

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
25.3 µM/ℓ	0.2	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site G1-4, Southern Bight of North Sea	van der Loeff 1980
29.0 µM/ℓ	0.3	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site G2, Southern Bight of North Sea	van der Loeff 1980
32.5 µM/ℓ	0.4	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site G3, Southern Bight of North Sea	van der Loeff 1980
12.8 µM/ℓ	0.1	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site G4, Southern Bight of North Sea	van der Loeff 1980
148.0 µM/ℓ	1.5	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site G5, Southern Bight of North Sea	van der Loeff 1980
141.0 µM/ℓ	1.4	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site G5-6, Southern Bight of North Sea	van der Loeff 1980
132.0 µM/ℓ	1.4	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Site G6, Southern Bight of North Sea	van der Loeff 1980
33.0 µM/ℓ	0.4	M.	Sand	N.R.	0-30	Squeezer	Spectro-photometric	Southern Bight of North Sea, Survey Offshore	van der Loeff 1980
75.0 mM/m	0.4	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site BF, Southern, North Sea	van Raaphorst et al. 1990
30.0 mM/m	0.1	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site FF, Southern, North Sea	van Raaphorst et al. 1990
5.0 µM/ℓ	0.04	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 100M, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
30.0 µM/ℓ	0.2	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 16AS, S. North Sea, Dogger Bank	van Raaphorst et al. 1990

(Sheet 13 of 15)

Table 1 (Continued)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
40.0 µM/ℓ	0.2	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 16S, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
10.0 µM/ℓ	0.1	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 21F, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
90.0 µM/ℓ	0.4	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 36S, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
50.0 µM/ℓ	0.2	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 51F, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
15.0 µM/ℓ	0.1	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 56M, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
55.0 µM/ℓ	0.4	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 62M, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
25.0 µM/ℓ	0.2	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 67F, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
35.0 µM/ℓ	0.1	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 75S, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
35.0 µM/ℓ	0.1	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 8S, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
40.0 µM/ℓ	0.1	M.	Sand/silt	0.1-0.5	0-100	Squeezer	Spectro-photometric	Site 97S, S. North Sea, Dogger Bank	van Raaphorst et al. 1990
15.0-400.0 µM/ℓ	0.8-2.2	M.	N.R.	0.1-1.3	0-48	Centrifuge	Spectro-photometric	Site 12, North Sea, The Netherlands	Lohse et al. 1993
70.0-265.0 µM/ℓ	0.7-2.6	M.	Silt/sand	N.R.	0-10	Centrifuge	Spectro-photometric	Bay of Morlaix, Brittany, France	Lerat, Lasserre, and le Corre 1990

(Sheet 14 of 15)

Table 1 (Concluded)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
0.5-14.3 mg/ℓ	0.6-17.0	M.	N.R.	1.5-9.3	0-48	Centrifuge	Spectro-photometric	Site 7, Orbetello Lagoon, Italy	Bonanni et al. 1992
56.0 µg/ℓ	0.04	M.	Silt	N.R.	N.R.	Vacuum sampler	Spectro-photometric	Brighton Beach, S. Africa	Oliff et al. 1970
328.0 µg/ℓ	0.9	M.	Silt	N.R.	N.R.	Vacuum sampler	Spectro-photometric	Umbogintwin Group S. Africa	Oliff et al. 1970
0.2 mM/ℓ	1.6	M.	Sand/silt/clay	0.3-4.0	1-5	Centrifuge	Spectro-photometric	East China Sea	Mackin and Aller 1984

(Sheet 15 of 15)

Table 2
Sediment Pore Water Concentrations of Ammonia From Dredged Material Sites and Related Information (i.e., salinity, grain size, percent total organic carbon, depth of collection and methods of collection and analysis, and sample location) Reported in Literature

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
42.0-86.0 mg/ℓ	602.4-678.4	F.	N.R.[3]	N.R.	0-10	Centrifuge	Ion Selective Electrode	Cal-Sal Channel, Lake Calumet, Chicago, IL	Schubauer-Berigan and Ankley 1991
729.0 mg/ℓ	512.0	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Site 217 E Chicago Harbor, Chicago, IL	U.S. Army Corps of Engineers 1994b
266.0 mg/ℓ	186.7	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Site 302 Chicago Harbor, Chicago, IL	U.S. Army Corps of Engineers 1994b
24.9 mg/ℓ	13.9	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Toledo Harbor LMO-1 Toledo, OH	U.S. Army Corps of Engineers 1994a
13.4 mg/ℓ	3.5	F.	N.R	N.R	N.R.	N.R.	N.R.	Toledo Harbor LM2-2 Toledo, OH	U.S. Army Corps of Engineers 1994a
3.8 mg/ℓ	1.8	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Toledo Harbor Ref Toledo, OH	U.S. Army Corps of Engineers 1994a
19.4 mg/ℓ	13.7	F.	N.R	N.R.	N.R.	N.R.	N.R.	Toledo Harbor RM0-1 Toledo, OH	U.S. Army Corps of Engineers 1994a
7.7 mg/ℓ	2.7	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Toledo Harbor LM1-2 Toledo, OH	U.S. Army Corps of Engineers 1994a
9.0 mg/ℓ	11.8	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Toledo Harbor LM2-3 Toledo, OH	U.S. Army Corps of Engineers 1994a

(Sheet 1 of 4)

[1] Reported concentrations converted to un-ionized ammonia using reported pH and salinity and the equation of Hampson (1977). Values were converted from mg/ℓ to µM/ℓ using a conversion factor (58.71).
[2] F. = Freshwater (<1 ppt); E. = Estuarine (1 to 30 ppt); M. = Marine (30 to 35 ppt).
[3] N.R. = Not Reported.

Table 2 (Continued)

Reported Total Ammonia Concentration, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
10.3 mg/ℓ	6.4	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Toledo Harbor LM4-5 Toledo, OH	U.S. Army Corps of Engineers 1994a
11.0 mg/ℓ	4.2	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Toledo Harbor LM5-6 Toledo, OH	U.S. Army Corps of Engineers 1994a
13.8 mg/ℓ	3.4	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Toledo Harbor RM1-2 Toledo, OH	U.S. Army Corps of Engineers 1994a
12.8 mg/ℓ	5.2	F.	N.R.	N.R.	N.R.	N.R.	N.R.	Toledo Harbor RM2-3 Toledo OH	U.S. Army Corps of Engineers 1994a
1.2-1.4 mg/ℓ	10.0-13.2	E.	Sand/ silt	8.1	0-2	Squeezer	N.R.	Site 3 San Francisco Bay, Oakland Inner	Carr, Williams, and Fragata 1989
28.5-29.0 mg/ℓ	54.1-55.0	E.	N.R.	N.R.	N.R.	N.R.	N.R.	San Francisco Bay, Oakland Outer	Moore and Dillon 1993
22.2 mg/ℓ	5.5	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Site 1 Oakland Outer Harbor	U.S. Army Corps of Engineers 1994c
21.5 mg/ℓ	5.3	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Site 2 Oakland Outer Harbor	U.S. Army Corps of Engineers 1994c
29.3 mg/ℓ	11.4	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Site 3 Oakland Outer Harbor	U.S. Army Corps of Engineers 1994c
36.7 mg/ℓ	19.1	E.	N.R.	N.R	N.R	N.R	N.R	Site 4 Oakland Outer Harbor	U.S. Army Corps of Engineers 1994c
34.8 mg/ℓ	21.3	E.	N.R	N.R	N.R.	N.R.	N.R.	Site 5 Oakland Outer Harbor	U.S. Army Corps of Engineers 1994c
7.0 mg/ℓ	1.1	E.	N.R.	N.R.	N.R.	N.R	N.R.	Site 6 Oakland Outer Harbor	U.S. Army Corps of Engineers 1994c
6.6 mg/ℓ	1.3	E.	N.R.	N.R.	N.R.	N.R	N.R.	Site 7 Oakland Outer Harbor	U.S. Army Corps of Engineers 1994c

(Sheet 2 of 4)

Table 2 (Continued)

Reported Total Ammonia Concentration, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
4.6 mg/ℓ	2.2	E.	N.R	N.R	N.R	N.R	N.R	Site 1 Oakland Inner Harbor	U.S. Army Corps of Engineers 1994c
9.8 mg/ℓ	4.8	E.	N.R	N.R	N.R	N.R	N.R.	Site 2 Oakland Inner Harbor	U.S. Army Corps of Engineers 1994c
6.5 mg/ℓ	2.5	E.	N.R	N.R	N.R.	N.R.	N.R.	Site 3 Oakland Inner Harbor	U.S. Army Corps of Engineers 1994a
6.2 mg/ℓ	3.8	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Site 1 Richmond Outer Harbor	U.S. Army Corps of Engineers 1994d
54.9 mg/ℓ	33.4	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Motby Reach A, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e
73.2 mg/ℓ	37.9	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Motby Reach B, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e
128.0 mg/ℓ	42.3	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Authur Kill Reach A NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e
122.0 mg/ℓ	49.9	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Author Kill Reach B, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e
109.8 mg/ℓ	39.7	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Author Kill Reach C, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e
48.8 mg/ℓ	32.0	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Port Elizabeth Reach A, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e
134.2 mg/ℓ	112.5	E.	N.R.	N.R.	N.R.	N.R.	N.R.	Claremont Reach II, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e

(Sheet 3 of 4)

Table 2 (Concluded)

Reported Total Ammonia Concentrations, units	NH_3[1], µM/ℓ	Salinity[2]	Grain Size	Percent TOC	Depth of Collected Sediment, cm	Method of Porewater Collection	Method of NH_3 Analysis	Sample Location	Citation
30.5 mg/ℓ	30.1	E.	N.R.	N.R.	N.R.	N.R.	N.R.	NY/NJ Ref Site	U.S. Army Corps of Engineers 1994e
42.0-42.5 mg/ℓ	102.6-120.7	M.	Sand/silt/Clay	0.03-0.8	0-2.5	Centrifuge	Ion Selective Electrode	San Francisco Bay, Oakland Cont.	Moore and Dillon 1993
97.6 mg/ℓ	59.9	M.	N.R.	N.R.	N.R.	N.R.	N.R.	Port Elizabeth Reach B, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e
85.4 mg/ℓ	53.6	M.	N.R.	N.R.	N.R.	N.R.	N.R.	Hackensack River Reach A, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e
122.0 mg/ℓ	100.4	M.	N.R.	N.R.	N.R.	N.R.	N.R.	Claremont Reach I, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e
85.4 mg/ℓ	57.5	M.	N.R.	N.R.	N.R.	N.R.	N.R.	Claremont Reach III, NY/NJ Fed. Project	U.S. Army Corps of Engineers 1994e

(Sheet 4 of 4)

Table 3
Effects Concentrations of Ammonia and Other Relevant Information (i.e., stage/size, test end points, duration) Reported in Literature for Freshwater and Marine Invertebrates and Fish

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Invertebrates											
Stenelmis sexlineata	Beetle	2.8 mm	Survival	4	0	25.0	8.7	469.7			USEPA 1984
Pycnocentria evecta	Caddisfly	Yes 6-10 mm	No survival	4	0	15.0	7.6	23.5			Hickey and Vickers 1994
Hydropsyche angustipennis	Caddisfly	10-15 mm	Survival	4	0	11.5	7.8-8.0	173.2			Williams et al. 1986
Philartcus quaeris	Caddisfly	Larva	Survival	4	0	13.3-21.0	7.8	593.1			Arthur et al. 1987
	Caddisfly	Larva	Survival	4	0	13.3	7.8	598.9			USEPA 1984
Lymnaca inermis	Insect	6-8 mm	Survival	4	0	11.5	7.8-8.0	93.9			Williams et al. 1986
Pachydiplax longipennis	Dragonfly	<233 days	Survival	4	0	12.0-20.0	8.0	>202.6		81.6	Diamond et al. 1993
Asellus racovitzai	Isopod	Adult	Survival	4	0	4.0-22.0	7.8-8.0	294.8			Arthur et al. 1987
	Isopod	Adult	Survival	4	0	4.0-11.9	7.8-8.0	172.6-290.7			USEPA 1984
Baetis rhodani	Mayfly	8-10 mm	Survival	4	0	11.5	7.8-8.0	99.8			Williams et al. 1986
Callibaetis montanus	Mayfly	10 mm	Survival	4	0	11.9	7.8	105.7			USEPA 1984

(Sheet 1 of 19)

[1] LC_{50} = Concentration estimated to in 50-percent mortality of the test organisms within a given period of time (usually 4 days); EC_{50} = concentration estimated to result in an effect other than mortality within a given period of time (usually 4 days).
[2] LOEC = Lowest concentration tested for which significant effects were reported.
[3] NOEC = Highest concentration tested for which no significant effects were reported.

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Invertebrates (Continued)											
Chironomus riparius	Mayfly	10-12 mm	Survival	4	0	11.5	7.8-8.0	96.9			Williams et al. 1986
Callibaetis skokianus	Mayfly	Nymph	Survival	4	0	10.8-13.0	7.7-7.9	229.0			Arthur et al. 1987
	Mayfly	Nymph	Survival	4	0	13.3	7.9	283.0			USEPA 1984
Deleatidium spp.	Mayfly	5-10 mm	Survival	4	0	15.0	7.6	26.4			Hickey and Vickers 1994
Ephamerella grandis	Mayfly	10-11 mm	Survival	4	0	12.0-13.2	7.8	226.0-345.0			USEPA 1984
Ephamerella ignita	Mayfly	8-10 mm	Survival	4	0	11.5	7.8-8.0	108.6			Williams et al. 1986
Zephlebia dentata	Mayfly	5-10 mm	Survival	4	0	15.0	8.2	>47.0			Hickey and Vickers 1994
Arcynopteryx parallela	Stonefly	19 mm	Survival	4	0	13.0-14.0	7.8	117.0-121.0			USEPA 1984
Pteronarcella badia	Stonefly	N.R.	Survival	24-30	0	12.1-13.0	7.8-8.0	85.1-268.3			USEPA 1984
Zealandobius furcillatus	Stonefly	5-10 mm	Survival	2	0	15.0	8.2	>46.9			Hickey and Vickers 1994
Ceriodaphnia acanthina	Cladoceran	<2 hr	Survival	4	0	24.0	7.06	45.2			USEPA 1984
Ceriodaphnia dubia	Cladoceran	<8 hr	Reproduction	7-9	0	24.0	6.5-8.0	4.7-59.3	2.3-65.8		Johnson and Crunkilton 1994

(Sheet 2 of 19)

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Invertebrates (Continued)											
Ceriodaphnia dubia	Cladoceran	Neonate	Survival	4	0	7.0-25.0	7.8-8.2	27.0-60.5			Nimmo et al. 1989
	Cladoceran	Neonate	Reproduction	7	0	25.0			41.1	36.4	Nimmo et al. 1989
Daphnia magna	Cladoceran	Adult	Survival, reproduction, and growth	21	0	19.5-20.0	8.3-8.6		51.1	24.7	Gersich and Hopkins 1986
	Cladoceran	Adult	Survival	2	0	19.5-20.0	8.4-8.6	172.6		68.1	Gersich and Hopkins 1986
	Cladoceran	Neonate	Survival	2	0	25.0	8.2	122.1			Parkhurst et al. 1979 and 1981
	Cladoceran	N.R.	Survival	28	0	22.1	8.09	89.8			USEPA 1984
	Cladoceran	<1 day	Survival	4	0	19.6-22.0	7.4-8.6	31.1-290.1			USEPA 1984
Daphnia pulicaria	Cladoceran	N.R.	Survival	2	0	14.0	8.0	68.1			DeGraeve, Overcast, and Bergman 1980
Moina rectirostris	Cladoceran	N.R.	Survival	1	0	25.0	8.3	88.1			USEPA 1984
Simocephalus vetulus	Cladoceran	Adult	Survival	2	0	17.0-20.4	8.1-8.3	100.4			Arthur et al. 1987
	Cladoceran	<1 day-Adult	Survival	4	0	17.5-24.0	7.1-8.3	35.8-134.5			USEPA 1984
Crangonyx spp.	Amphipod	8-42 days	Survival	4	0	20	8	40.5-112.2		19.4-99.2	Diamond et al. 1993
	Amphipod	8-42 days	Growth	21	0	12.0-20.0	8			19.4	Diamond et al. 1993

(Sheet 3 of 19)

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], μM/ℓ	LOEC[2] μM/ℓ	NOEC[3] μM/ℓ	Citation
Freshwater Invertebrates (Continued)											
Crangonyx pseudogracilis	Amphipod	Adult	Survival	4	0	4.0-24.9	8.0-8.2	183.2			Arthur et al. 1987
	Amphipod	Adult	Survival	4	0	4.0-25.0	8.0-8.2	85.7-330.6			USEPA 1984
Gammarus pulex	Amphipod	8-12 mm	Survival	4	0	11.5	7.8-8.0	120.4			Williams et al. 1986
Paracalliope fluviatilis	Amphipod	1-3 mm	Survival	2	0	15.0	7.6	10.6			Hickey and Vickers 1994
Asellus aquaticus	Crustacean	8-10 mm	Survival	4	0	11.5	7.8-8.0	135.0			Williams et al. 1986
Paratya curvirostris	Shrimp	10-15 mm	Survival	4	0	15.0	8.2	>47.0			USEPA 1984
Orconectes immunis	Crayfish	Adult	Survival	4	0	4.6-17.1	7.9-8.2	1,075.0			Arthur et al. 1987
	Crayfish	Adult	Survival	4	0	4.6	8.2	1,340.0			USEPA 1984
Orconectes nais	Crayfish	2.78 cm	Survival	4	0	26.0-27.0	7.6-9.0	185.0			USEPA 1984
Procambarus clarkii	Crayfish	20-30 days, 2.1 cm	Survival	4	0	20.0	8.0	160.0		75.7	Diamond et al. 1993
	Crayfish	<2.5 cm	Survival	4	0	12.0	8.0	>138.0			Diamond et al. 1993
	Crayfish	20-30 days, 2.1 cm	Survival and growth	21	0	20.0	8.0			>20.5	Diamond et al. 1993

(Sheet 4 of 19)

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Invertebrates (Continued)											
Mulinia transversum	Fingernail Clam	Adult	Survival	4	0	5.4-20.5	8.1-8.6	54.6-75.7			USEPA 1984
	Fingernail clam	Adult	Survival	4	0	5.4-20.5	8.1-8.6	64.6			Arthur et al. 1987
	Fingernail clam	N.R.	Survival	42	0	21.7	7.8-8.8	4.3			USEPA 1984
	Fingernail clam	N.R.	Growth	42	0	21.7	7.8-8.8	2.1			USEPA 1984
	Fingernail clam	N.R.	Growth	14	0	22.0	8.1-8.2		24.1		USEPA 1984
Sphaerium novauzelandie	Fingernail clam	2-3 mm	Survival and burial	4	0	15.0	8.2	34.6			Hickey and Vickers 1994
Helisoma trivolvis	Snail	Adult	Survival	4	0	19.9-22.0	7.9-8.2	139.0			Arthur et al. 1987
	Snail	Adult	Survival	4	0	12.9	8.2	162.0			USEPA 1984
Lymnaea stagnalis	Snail	25-30 mm	Survival	4	0	11.5	7.8-8.0	58.7			Williams et al. 1986
Potamopurgus antipodarum	Snail	2-3 mm	Survival and burial	4	0	15.0	7.6-8.2	18.2-25.8			Hickey and Vickers 1994
Physa fontinalis	Snail	10-12 mm	Survival	4	0	11.5	7.8-8.0	99.8			Williams et al. 1986
Physa gyrina	Snail	Adult	Survival	4	0	4.0-24.9	8.0-8.2	114.0			Arthur et al. 1987
	Snail	Adult	Survival	4	0	4.0-24.9	8.0-8.2	93.4-146.0			USEPA 1984
Potamopyrgus jenkinsi	Snail	Breeding adults	Survival	4	0	15.0-20.0	7.5-8.0	32.9-49.9	47.6	25.8	Watton and Hawkes 1984

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Invertebrates (Concluded)											
Potamopyrgus jenkinsi	Snail	1-2 mm; 4-12 weeks	Survival	4	0	15.0-20.0	7.7-7.8	18.2	31.1	13.5	Watton and Hawkes 1984
	Snail	Senescent adults	Survival	4	0	15.0-20.0	7.2-8.0	21.7-28.8	18.2	22.3	Watton and Hawkes 1984
Tubifex tubifex	Tubificid worm	N.R.	Survival	4	0	12.0	8.2	158.5			USEPA 1984
Lumbriculus variegatus	Oligochaete	10-25 mm	Survival	4	0	15.0	8.2	40.5			Hickey and Vickers 1994
Limnodrilus hoffmeisteri	Oligochaete	30-40 mm	Survival	4	0	11.5	7.8-8.0	112.7			Williams et al. 1986
Polycelis tenuis	Flatworm	10-12 mm	Survival	4	0	11.5	7.8-8.0	41.7			Williams et al. 1986
Freshwater Fish											
Salmo salar	Atlantic Salmon	150 mm, (2 years)	Survival	1	0	12.0	7.7	5.3-8.8			Alabaster, Shurben, and Knowles 1979
Oncorhynchus tshawytscha	Chinook salmon	1-7 g; Juvenile	Survival	4	0	7.0	7.8-8.1	26.42			Servizi and Gordon 1990
	Chinook salmon	14.4-18.1 g	Survival	4	0	12.0-13.5	7.8	23.4-28.0			USEPA 1984
Oncorhynchus kisutch	Coho salmon	Juvenile	Survival	4	0	15.0	8.0-8.2	16.0-51.7			USEPA 1984
Oncorhynchus gorbuscha	Pink salmon	Late alevins and fry	Survival	4	0	3.7-4.8	6.3-6.5	4.7-5.9			USEPA 1984
Salvelinus fontinalis	Brook trout	3.12-3.4 g	Survival	4	0	10.6-13.0	7.8-7.9	56.5-61.6			USEPA 1984

(Sheet 6 of 19)

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Fish (Continued)											
Salmo trutta	Brown trout	0.9-1.2 g	Survival	4	0	13.2-14.0	7.8	35.0-41.2			USEPA 1984
Oncorhynchus clarki	Cutthroat trout	1-3 g; Fry	Survival	4	0	12.0-13.0	7.8	29.4-47.0			Thurston, Russo, and Smith 1978
	Cutthroat trout	1-3 g; Fry	Survival	36	0	12.0-13.0	7.8	32.9			Thurston, Russo, and Smith 1978
	Cutthroat trout	3.6-4.1 g	Survival	4	0	10.0	7.7	17.4-19.2			Thurston, Chakonmakos, and Russo 1981b
	Cutthroat trout	1-3.4 g	Survival	4	0	12.2-13.0	7.8	30.5-47.0			USEPA 1984
	Cutthroat trout	N.R.	Survival	29-36	0	12.2-13.0	7.8	20.0-33.0			USEPA 1984
Oncorhynchus aquabonita	Golden trout	0.09 g	Survival	4	0	13.2	8.06	44.3			USEPA 1984
Onchorhynchus mykiss	Rainbow trout	3.3-22.4 g	Survival	4	0	3.6-18.7	7.7-8.3	31.1			Arthur et al. 1987
	Rainbow trout	N.R.	Survival	4	0	14.0	8.0	45.2			DeGraeve et al. 1980
	Rainbow trout	Eggs; <24 hr post-fert.	Survival	73	0	11.5-17.0	7.52		1.6		Solbe and Shurben 1989
	Rainbow trout	Eyed larva; 24 days post-fert.	Survival	49	0	11.5-17.0	7.52		7.6	4.2	Solbe and Shurben 1989

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Fish (Continued)											
Onchorhunchus mykiss	Rainbow trout	8-11 g; 9-10 cm	Survival	4	0	13.0-15.0	6.5-9.0	7.6-31.3			Thurston, Russo, and Vinogradon 1981
	Rainbow trout	2-10 g; 6-10 cm	Survival	4	0	12.0-13.0	7.8-7.9	18.8-47.0			Thurston et al. 1981a
	Rainbow trout	604 g; 30 months	Gill lesions and disease	1,825	0	9.3	7.7		1.2	0.6	Thurston et al. 1984
	Rainbow trout	230-293 g	Survival	4	0	7.9-8.8	7.6-7.8	17.4			Thurston, Chakonmakos, and Russo 1981b
	Rainbow trout	18-21 g	Survival	4	0	9.3-9.8	7.8-7.9	29.4			Thurston, Chakonmakos, and Russo 1981b
	Rainbow trout	2-2.5 kg	Survival	4	0	7.5-8.8	7.5-7.8	9.6			Thurston , Chakonmakos, and Russo 1981b
	Rainbow trout	N.R.	Growth	30	0	10.0	8.0		5.9		USEPA 1984
	Rainbow trout	Sac-fry-adult	Survival	4	0	3.0-19.2	6.5-9.0	9.3-64.0			USEPA 1984
	Rainbow trout	N.R.	Survival	72	0	14.5	7.4	3.3			USEPA 1984
	Rainbow trout	N.R.	Survival	12-35	0	9.8-13.2	7.6-7.9	15.4-38.7			USEPA 1984
Stizostedion vitreum	Walleye	13.4-22.6 g	Survival	4	0	3.7-19.0	7.7-8.3	38.8			Arthur et al. 1987
	Walleye	6 days 13.4-22.6 g	Survival	4	0	3.7-18.2	7.7-8.3	29.9-64.6			USEPA 1984

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Fish (Continued)											
Cyprinella lutrensis	Red shiner	0.40 g	Survival	4	0	24.0	8.2-9.2	166.2-185.5			USEPA 1984
Notemigonos crysoleucas	Golden shiner	8.7 g	Survival	4	0	24.5	7.5	42.3			USEPA 1984
Cyprinella spilopterus	Spotfin shiner	31-85 mm; 0.5 g	Survival	4	0	25.7-26.0	7.7-8.5	70.5-95.1			USEPA 1984
Cyprinella whipplei	Steelcolor shiner	0.5 g	Survival	4	0	25.7	7.9	73.4			USEPA 1984
Campostoma anonalum	Stoneroller	2.1 g	Survival	4	0	25.7	7.8	101.0			USEPA 1984
Pimephales promelas	Fathead minnow	1.6-1.9 g	Survival	4	0	3.4-26.1	7.9-8.1	127.4			Arthur et al. 1987
	Fathead minnow	N.R.	Survival	4	0	14.0	8.0	93.4			DeGraeve, Overcast, and Bergman 1980
	Fathead minnow	10 mm; Larva	Survival	4	0	6.0-20.0	7.7-8.2	11.2-65.8			Nimmo et al. 1989
	Fathead minnow	25 mm; Juvenile	Survival	4	0	6.0-20.0	7.7-8.2	17.6-82.2			Nimmo et al. 1989
	Fathead minnow	1.8-2.0 g; 4.7-5.6 cm	Survival	4	0	12.0-14.0	6.5-9.0	11.6-81.0			Thurston et al. 1981a
	Fathead minnow	1.0-1.4 g; 4.6-5.1 cm	Survival	4	0	14.0-22.0	7.8-8.2	76.3-199.6			Thurston, Russo, and Phillips 1983
	Fathead minnow	0.09-0.19 g; 2.0-2.6 cm	Survival	4	0	13.0-16.0	7.6-7.9	44.0-88.1			Thurston, Russo, and Phillips 1983

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Fish (Continued)											
Pimephales promelas	Fathead minnow	0.42-0.8 g; 3.2-4.2 cm	Survival	4	0	13.0-22.0	7.7-7.9	47.0-108.6			Thurston, Russo, and Phillips 1983
	Fathead minnow	1.4-1.7 g; 5.2-5.6 cm	Survival	4	0	12.0-22.0	7.6-7.9	57.5-119.2			Thurston, Russo, and Phillips 1983
	Fathead minnow	0.22-0.42 g; 2.7-3.1 cm	Survival	4	0	13.0-22.0	7.7-8.1	47.0-158.5			Thurston, Russo, and Phillips 1983
	Fathead minnow	3-5 days; Larva	Survival, growth, and reproduction	354-379	0	24.0-24.4	8.0		53.4	21.7	Thurston et al. 1986
	Fathead minnow	0.032-2.3 g	Survival	4	0	3.4-26.0	6.5-8.7	14.1-160.3			USEPA 1984
Gambusia affinis	Mosquito-fish	Adult females	Survival	4	0	17.0-26.0	7.6-8.0	140.9-187.9			USEPA 1984
Carassius auratus	Goldfish	N.R.	Survival	1	0	22.0	7.9	422.8			USEPA 1984
Poecilia reticulata	Guppy	8-8.7 mm	Survival	4	0	25.0	7.0-7.5	85.1-93.4			USEPA 1984
Etheostoma nigrum	Johnny darters	38 mm	Survival	4	0	6.0-20.0	7.9-8.2	10.5-67.5			Nimmo et al. 1989
Etheostoma spectabile	Orange-throat darter	0.71-0.78 g	Survival	4	0	21.0-22.0	7.7-8.5	52.8-62.8			USEPA 1984
Lepomis macrochirus	Bluegill	0.049-1.2 g	Survival	4	0	4.5-26.6	7.6-9.0	32.3-174.4			USEPA 1984
	Bluegill	<21 days	Survival	4	0	12.0	8.0	31.1		21.1	Diamond et al. 1993

(Sheet 10 of 19)

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Fish (Continued)											
Lepomis macrochirus	Bluegill	1.7 cm	Survival and growth	14	0	20.0	8.0			18.2	Diamond et al. 1993
	Bluegill	<21 days	Survival and growth	14	0	12.0	8.0			18.2	Diamond et al. 1993
	Bluegill	1.7 cm	Survival	4	0	20.0	8.0	59.9		17.0	Diamond et al. 1993
Lepomis cyanellus	Green sunfish	0.063-8.4 g	Survival	4	0	12.0-26.0	6.6-8.7	34.6-123.9			USEPA 1984
Lepomis gibbosus	Pumpkin-seed	4.5-18.9 g	Survival	4	0	12.0-15.7	7.7	8.2-50.5			USEPA 1984
Micropterus salmoides	Largemouth bass	0.09-6.3 g	Survival	4	0	22.0-28.0	8.0-8.1	58.7-99.8			USEPA 1984
Micropterus dolomieui	Smallmouth bass	29 mm, 265 mg; 40 days	Survival	4	0	22.0	6.5-8.7	40.8-104.5			Broderius et al. 1985
	Smallmouth bass	Late embryo	Growth	32	0	22.0	6.6-8.7		2.0-50.8	8.7-35.9	Broderius et al. 1985
Morone americana	White perch	76 mm	Survival	4	0	16.0	6.0-8.0	8.8-30.5			USEPA 1984
Prosopium williamsoni	Mountain whitefish	56.9-177 g	Survival	4	0	12.0	7.7-7.8	8.4-27.8			USEPA 1984
Tilapia aurea	Blue tilapia	7-9 cm	Survival	3	0	25.0	7.1-7.7	138.0	132.7	129.2	Redner and Stickney 1979
	Blue tilapia	N.R.	Survival	3	0	25.0	7.3-7.4	167.4			USEPA 1984
Catostomus commersoni	White sucker	5.2-12.6 g	Survival	4	0	3.6-15.3	7.8-8.2	89.8			Arthur et al. 1987

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Fish (Continued)											
Catostomus commersoni	White sucker	110 mm	Survival	4	0	20.0	7.8	33.5			Nimmo et al. 1989
	White sucker	5.6-11.4 g	Survival	4	0	3.6-22.5	7.8-8.3	44.6-130.3			USEPA 1984
Catostomus platyrhynchus	Mountain sucker	45.3-63.3 g	Survival	4	0	11.7-13.0	7.7	39.2-48.1			USEPA 1984
Cottus bairdi	Mottled sculpin	1.8 g	Survival	4	0	12.4	8.02	81.6			USEPA 1984
Channa punctatus	Lungfish	15-25 cm	Decreased ovarian wt.	3 months	0	27.0	7.4		14.7		Dey and Bhattacharya 1989
Cyprinus carpio	Carp	Fingerling	Gill lesions	15	0	28.0	7.7		11.1		Manissery and Madhyastha 1993
	Carp	N.R.	Survival	4	0	28.0	7.6	64.6			USEPA 1984
Ictalurus punctatus	Channel catfish	3.5-6.4 g	Survival	4	0	3.5-19.6	7.8-8.1	50.5			Arthur et al. 1987
	Channel catfish	7 days; Juvenile	Growth	7	0	24.0	8.2		12.4	5.5	Bader and Grizzle 1992
	Channel catfish	1 day; Larvae	Growth	7	0	24.0	8.2		13.7	4.8	Bader and Grizzle 1992
	Channel catfish	7 days; Juvenile	Survival	7	0	24.0	8.2	94.5	20.0	12.4	Bader and Grizzle 1992
	Channel catfish	1 day; Larva	Survival	7	0	24.0	8.2	71.0	28.9	20.5	Bader and Grizzle 1992

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Freshwater Fish (Concluded)											
Ictalurus punctatus	Channel catfish	18 g; Juvenile	Growth	31	0	28.0	8.4		2.9		Colt and Tchobanoglous 1978
	Channel catfish	18 g; Juvenile	Survival	4	0	28.0	8.4	93.9	2.9		Colt and Tchobanoglous 1978
	Channel catfish	<110 days	Survival	4	0	20.0	8.0	>95.7		>95.7	Diamond et al. 1993
	Channel catfish	Fingerling	Growth	27-29	0	25.0	7.4-7.8		7.04	3.5	Robinette 1976
	Channel catfish	7-13 cm	Survival	2	0	21.0-25.0	7.0-9.0	81.6-106.9			Tomasso et al. 1980
	Channel catfish	0.5-12.8 cm	Survival	4	0	3.5-26.0	7.7-8.4	29.4-246.6			USEPA 1984
Morone chrysops *Morone saxatilis*	Bass	1-2 g	Survival	4	0-24	25.0	6.8-7.4	18.8-41.1			Weirich, Tomasso, and Smith 1993
Morone saxatilis	Stripped bass	Larva-juvenile	Survival	4	5-34	15.0-23.0	7.1-8.2	34.0-95.1			USEPA 1989
Oncorhunchurs kisutch	Coho salmon	N.R.	Survival	1	25	15.0	7.5	29.4			USEPA 1989
Oncorhunchus tshawytscha	Chinook salmon	N.R.	Survival	1	0-28	11.0-13.0	6.9-8.6	21.1-123.3			USEPA 1989
Marine Invertebrates											
Homarus americanus	American lobster	76 mm; Larva	Survival	4	33	21.9	8.1	130.0			USEPA 1989

(Sheet 13 of 19)

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Marine Invertebrates (Continued)											
Homarus americanus	American lobster	76 mm; Larva	Survival	8	33	21.9	8.1	105.0			USEPA 1989
	American lobster	Stage 4 Post-larva	Survival	4	30	20.0		139.0			Young-Lai, Charmantier-Daures, and Charmantier 1991
	American lobster	Adult	Survival	4	30	5.0		301.0			Young-Lai, Charmantier-Daures, and Charmantier 1991
	American lobster	Stage 1 larva	Survival	4	30	20.0		42.3			Young-Lai, Charmantier-Daures, and Charmantier 1991
	American lobster	Stage 2 larva	Survival	4	30	20.0		99.8			Young-Lai, Charmantier-Daures, and Charmantier 1991
	American lobster	Adult	Survival	4	30	20.0		191.0			Young-Lai, Charmantier-Daures, and Charmantier 1991
	American lobster	Stage 3 larva	Survival	4	30	20.0		125.0			Young-Lai, Charmantier-Daures, and Charmantier 1991
Ampelisca abdita	Amphipod	N.R.	Survival	4	30	15.0	8.0	47.0	26.2	13.9	Kohn et al. 1994
	Amphipod	0.7-1.0 mm sieved size fraction	Survival	10	28-32	20.0	7.5-8.2	55.8[4]	58.7[4]	<2.9[4]	SAIC 1992
Eohaustorius estuarius	Amphipod	N.R.	Survival	4	30	15.0	8.0	147.0	132.0	76.2	Kohn et al. 1994

(Sheet 14 of 19)

[4] Pore water concentrations.

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Marine Invertebrates (Continued)											
Eohaustorius estuarius	Amphipod	N.R.	Survival	10			6.0-9.0	7.6-164.0			Ogle and Hansen 1994
Grandidierella japonica	Amphipod	N.R.	Survival	4	30	15.0	8.0	200.0	18.6	0.5	Kohn et al. 1994
Rhepoxynius abronius	Amphipod	N.R.	Survival	4	30	15.0	8.0	94.0	78.6	39.2	Kohn et al. 1994
Eucalanus elongatus	Copepod	N.R.	Survival	7	30	20.3	8.0	39.1			USEPA 1989
	Copepod	Adult	Survival	4	34	20.5	8.0	50.9			USEPA 1989
Eucalanus pileatus	Copepod	N.R.	Survival	7	34	20.5	8.2	41.4			USEPA 1989
	Copepod	Adult	Survival	4	34	20.5	8.2	46.4			USEPA 1989
Macrobrachium rosenbergii	Prawn	N.R.	Survival	1	1-4	28.0		38.8-210.0			USEPA 1989
	Prawn	N.R.	Growth	42	30-34	28.0			7.0		USEPA 1989
	Prawn	3-8 days; Larva	Survival	4	12	28.0	6.8-8.3	22.3-76.3			USEPA 1989
	Prawn	N.R.	Growth	7	12	28.0	6.8-7.6		6.4-37.0		USEPA 1989
	Prawn	N.R.	Survival	6	12	28.0	6.8-8.3	15.3-79.8			USEPA 1989

(Sheet 15 of 19)

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Marine Invertebrates (Continued)											
Penaeus chinensis	Prawn	4 cm; 0.36 g; juveniles	Survival	5	33	26.0	7.9	84.5	75.2	49.9	Chen et al. 1990
Brachionus plicatilis	Rotifer	N.R.	Survival	1	23	23.0		1,230.0			USEPA 1989
Mysidopsis bahia	Mysid	<48 hr	Growth	32	31	25.0	8.0		4.3	2.9	Miller et al. 1990
	Mysid	<48 hr	Survival	4	10-33	23.0-27.0	6.8-9.1	13.5-232.0			Miller et al. 1990
	Mysid	1-5 days; Juvenile	Survival	4	10-31	19.3-25.0	6.8-9.2	13.5-200.0			USEPA 1989
Palaemonetes pugio	Grass shrimp	<20 mm	Survival	2	10	20.0	7.5	70.5			Burton and Fisher 1990
	Grass shrimp	Larva	Survival	4	10	20.4	7.9	62.2			USEPA 1989
	Grass shrimp	N.R.	Survival	2		20.0	8.0-8.2	20.0-31.1			USEPA 1989
Latreutes fucorum	Sargassum shrimp	0.045 g	Survival	21	28	22.3	8.2			25.8	USEPA 1989
	Sargassum shrimp	0.045 g	Survival	4	28	23.4	8.1	37.5-54.9			USEPA 1989
Penaeus japonicus	Shrimp	Post-larva	Survival	4	36	25.0		76.3			Lin et al. 1993
	Shrimp	Zoea	Survival	4	36	25.0		35.2-41.1			Lin et al. 1993
	Shrimp	Post-larva	Survival	20	36	25.0		76.3			Lin et al. 1993
	Shrimp	Late juvenile	Hypo-osmotic reg.	2	36-15	20.0			76.3	41.1	Lin et al. 1993

(Sheet 16 of 19)

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Marine Invertebrates (Concluded)											
Penaeus japonicus	Shrimp	Nauplii	Survival	2	36	25.0		29.4			Lin et al. 1993
	Shrimp	Late juvenile	Survival	4	36	20.0		182.0			Lin et al. 1993
	Shrimp	Mysis	Survival	4	36	25.0		53.0			Lin et al. 1993
Penaeus monodon	Shrimp	0.50-2.32 g	Survival	4	41	17.0-25.0	8.2-8.5	84.0			Wajsbrot et al. 1990
Penaeus setiferus	White shrimp	N.R.	Survival	21	30-34	28.0		42.3			USEPA 1989
Mytilus edulis	Clam	Embryo	Development	2				25.2			Ogle and Hansen 1994
Rangia cuneata	Clam	Adult	Survival	4	9	20.2	8.0	181.0			USEPA 1989
Mercenaria mercenaria	Hard clam	5.0 mm, Juvenile	Survival	4	35	20.0	7.7-8.2	539.0			Epifanio and Srna 1975
	Hard clam	30.0 mm, Adult	Survival	4	35	20.0	7.7-8.2	371.0			Epifanio and Srna 1975
Crassostrea virginica	Oyster	15 mm, Juvenile	Survival	4	35	20.0	7.7-8.2	977.0			Epifanio and Srna 1975
	Oyster	55 mm, Adult	Survival	4	35	20.0	7.7-8.2	2,765.0			Epifanio and Srna 1975
Dinophilus gyrociliatus	Polychaete	1-2 d Post-emergent female	Reproduction	7	25	20.0	8.0		11.5	5.3	Carr, Williams, and Fragata 1989
Strongylocentrotus purpurates	Urchin	Embryo	Development	2				7.6			Ogle and Hansen 1994

(Sheet 17 of 19)

Table 3 (Continued)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Marine Fish											
Menidia beryllina	Inland silversides	20-25 days	Survival	4	0	12.0-20.0	8.0	42.9-66.4			Diamond et al. 1993
	Inland silversides	1-2 weeks; Larva	Growth	28	31	25.0	7.8		9.6	5.4	Miller et al. 1990
	Inland silversides	1-2 weeks; Larva	Survival	4	11-33	18.0-26.5	6.9-9.1	28.8-113.9			Miller et al. 1990
	Inland silverside	7-14 days; Larva	Survival	4	11-33	18.0-33.0	6.9-9.0	28.8-87.5			USEPA 1989
Menidia menidia	Atlantic silverside	Juvenile	Survival	4	8-10	11.0-25.0	7.0-9.0	56.9-86.3			USEPA 1989
	Atlantic silverside	N.R.	Survival	28	10	25.0			17.6		USEPA 1989
Cyprionodom variegatus	Sheepshead minnow	37-52 days	Survival	4		12.0	8.0	>91.6		61.1	Diamond et al. 1993
	Sheepshead minnow	12-13 mm; Larva	Survival	4	30-32	13.0-32.0	7.6-8.1	123.3-205.5			Miller et al. 1990
	Sheepshead minnow	Larva and adult	Survival	4	10-32	10.0-25.0	7.6-8.1	123.3-205.5			USEPA 1989
Fundulus heteroclitus	Killifish	<23 days	Survival	2	10	20.0	7.5	93.9			Burton and Fisher 1990
Gasterosteus aculeatus	3-Spined stickleback	32-60 mm	Survival	4	11-34	15.0-23.0	7.6-8.4	98.6-329.0			USEPA 1989
Monacanthus hispidus	Planehead filefish	0.4-0.7 g	Survival	4	28	23.4	8.1	40.5-58.0			USEPA 1989

(Sheet 18 of 19)

Table 3 (Concluded)

Species	Common Name	Stage/Size	End Point	Duration days	Salinity ppt	Temperature °C	pH	LC_{50} or EC_{50}[1], µM/ℓ	LOEC[2] µM/ℓ	NOEC[3] µM/ℓ	Citation
Marine Fish (Concluded)											
Leiostomus xanthurus	Spot	Juvenile	Survival	4	9	20.4	7.9	61.1			USEPA 1989
Morone americana	White perch	76 mm; Juvenile	Survival	4	14	16.0	8.0	125.0			USEPA 1989
Mugil cephalus	Striped mullet	N.R.	Survival	21		22.3	8.2	55.8			USEPA 1989
	Striped mullet	0.4-10.0 g	Survival	4	10	21.0-23.0	8.0-8.1	69.9-140.0			USEPA 1989
S. Salar	Atlantic Salmon	150 mm; 2 years)	Survival	1	30	12.0	7.7	7.0-17.6			Alabaster et al. 1979
P. americanus	Winter flounder	1 day; Larva	Survival	4	31	7.5	7.9-8.1	25.8-31.1			USEPA 1989
S. ocellatus	Red drum	Embryo-larva	Survival	4	28-32	25.0-26.0	8.0-8.2	32.0			USEPA 1989

(Sheet 19 of 19)

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13. ABSTRACT *(Maximum 200 words)*

Generally, ammonia is not treated as a contaminant of concern in the regulatory evaluation of dredged material since it undergoes rapid oxidation and dilution during dredging and disposal. However, because dredged material is evaluated using effects-based testing (i.e., whole sediment and elutriate toxicity tests), there is the potential for ammonia to exert toxicity and confound the regulatory decision-making process. To evaluate the potential for ammonia toxicity in dredged material bioassays, a literature review and survey of U.S. Army Corps of Engineers Divisions and Districts was conducted. Data included reported environmental pore water exposure concentrations of ammonia and effects concentrations shown to cause toxicity in laboratory studies with aquatic species. The majority of reported effect concentrations (>45 and >25 percent fish and invertebrates, respectively) were <40 µM NH_3/ℓ; environmental pore water concentrations were >40 µM/ℓ (10-percent exposure concentrations and 30-percent dredged material exposure concentrations). This comparison of reported exposure and effects concentrations suggests that a risk of pore water toxicity in dredged material bioassays may be significant. However, a number of biases in this limited data set are discussed that must be considered before any definitive conclusions can be drawn.

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